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MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION TRAINING BRANCH



WASHINGTON, D. C.

August, 1919



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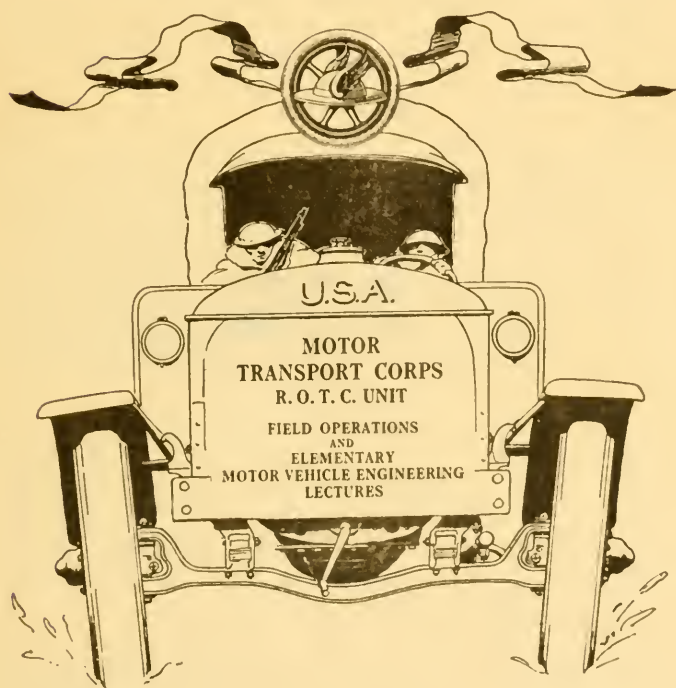
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TENTATIVE MANUAL OF INSTRUCTION.

MOTOR TRANSPORT CORPS.

RESERVE OFFICERS' TRAINING CORPS UNITS.

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MOTOR TRANSPORT CORPS
R.O.T.C. UNITS

FIELD OPERATIONS

FIELD OPERATIONS.

LECTURE I.*

THE MOTOR TRANSPORT CORPS.

The use of motor vehicles in the United States Army extends back to 1903, when there were a few passenger automobiles used, principally in Washington and at the headquarters of territorial departments. In 1906 six motor cars were supplied to the army of pacification in Cuba, and during the following year, 1907, a few motor trucks were purchased, principally for use at the supply depots of the Quartermaster Department. A few trucks continued to be purchased for the same purposes from year to year until, in 1912, a consistent effort was made to collect data on the upkeep of motor trucks, to enable the Army to take advantage of the then rapidly developing automotive industry in the United States.

In 1912 the Quartermaster Corps prepared the first general specifications for motor trucks, and in the fiscal year 1914 these specifications, amended to that date, governed all purchases made. These specifications are quite interesting at the present date. They stated, in part, as follows: "The Quartermaster Corps has adopted general specifications for an automobile truck which provides for a maximum weight of 5,000 pounds for truck complete, and the carrying capacity has been fixed at $1\frac{1}{2}$ tons, with a safe overload of 20 per cent." It is seen right here where motor transportation has been influenced by the old wagon transportation of the Army. That is, the capacity of its standard truck at that time was made the same as that of the standard 6-mule escort wagon. This old wagon was a splendid vehicle that had demonstrated its value ever since the Civil War, and was admirably suited for the poor roads and undeveloped country that it was used on since that time. From this point, by degrees, the present standard truck was developed, and the Army has been given a vehicle far better suited to its needs than any commercial vehicle, and equal to any of them in efficiency.

During these years, first the Quartermaster Department, and later the Quartermaster Corps, handled the motor vehicle business of the Army through its Transportation Division although other branches of the service, for instance, the Engineers, Signal Corps, Ordnance, and Medical Corps, purchased some motorized equipment for their own special needs.

The slow development of motor transportation in the American Army, prior to 1916, was due to three factors. First, the Army was called upon for very little mobile operation. Second, in such field

* The instructor should supplement all lectures by reference to "Manual of the Motor Transport" as prepared for the American Expeditionary Forces.

operations as it did conduct animal transportation sufficed. Third, experience with motor vehicles had been confined largely to depots and army posts, and in this work, necessarily of a short haul nature, motor vehicles could not compete with animal transportation in the matter of expense, and this fact more than any other handicapped the Army in asking appropriations from Congress for motor vehicles.

In March, 1916, it became necessary to equip an adequate military force to cross the Mexican border for the capture of the bandits who had raided the town of Columbus, N. Mex. Pursuant to a request from the Southern Department, the Quartermaster General's Office purchased the necessary vehicles for two truck companies. The trucks were of $1\frac{1}{2}$ -ton capacity, and to man these trucks, since no provision existed in the Army at that time for enlisted men as drivers, civilian personnel was hired at the factories where the trucks were manufactured. There were at first but two complete truck companies organized in the United States. These two companies, one from the Jeffrey Motors Co., Kenosha, Wis., and the other from the White Motors Co., Cleveland, Ohio, left March 15 and 16 and went by special train to Columbus, N. Mex. They were rapidly followed by other truck companies organized in the same way. Each truck company was equipped with the necessary tank trucks for carrying gasoline, oil, and water, and with two passenger cars.

With the experience of the Mexican border operations, under their severe conditions, it is apparent that many faults were developed in some of the commercial trucks in use. Some of these faults were of minor character which could be easily corrected, while others were of a much more serious nature and required notice in considering design of trucks. It was found, however, that the provisions of the specifications issued by the Quartermaster General's office were most suitable under these conditions. The various truck manufacturers sent their engineers to study these difficulties, with a view to making recommendations for their improvement and their observations and recommendations proved of great value in the standardization of trucks for military service.

On June 30, 1916, vehicles for 15 motor truck companies, consisting of 27 cargo trucks, all $1\frac{1}{2}$ -ton capacity, each with necessary auxiliaries, had been purchased and were in operation along the Mexican border, or in the vicinity thereof, ready to be placed in operation. These companies operated from Columbus, N. Mex., to a point more than 300 miles beyond the border. It was found that even over the rough country which these trucks traveled, they averaged somewhat more than 80 miles per day, in some instances as high as 90 miles. Roads, as they existed in that country, were beyond comparison and it was necessary to make fresh tracks over the prairie for operation of these vehicles.

In a report made at that time, the following extract is of interest:

"Among officers of experience with motor trucks, it is known that speed is the greatest menace to the successful operation of the truck. It was the hardest thing to control, far greater than anything else in connection with motor trucks."

The experience gained by officers of the Army in operation of motor trucks and as managers of truck trains on the Mexican border

was of greatest value in enabling them to handle this line of transportation during the World War.

During this period the Office of the Quartermaster General continued its efforts, in conjunction with the Society of Automotive Engineers, manufacturers and other Government departments, to develop specifications for motor trucks with a view to making changes that would conform to the exact needs of the Government.

The use of trailers in conjunction with motor trucks in the very rough country of Mexico, through which motor transportation operated, was considered unsatisfactory. Nevertheless, where specially designed tractors were used, trailers were very satisfactory. This is really the place they should occupy in the transport problem.

After the United States entered the World War, the first motor transport unit to embark was the First Supply Train, consisting of four companies with headquarters detachment, organized at Fort Sam Houston, Tex., in May, 1917.

This command embarked for France in June, 1917, arriving on the 23d of the same month, and formed the beginning of what developed into the extensive Motor Transport Corps of the American Expeditionary Forces. At this time, motor transportation was still handled by the Quartermaster of the Expeditionary Forces and in August, 1917, his office submitted an estimate of the motor transport personnel that would be necessary for an army of 5 corps or 30 divisions. This estimate was about 40,000 men and, in spite of the limited experience on which it was based, it was only about 4,000 men short of what, after a year of experience with the war, was found to be necessary for an army of 30 divisions. This estimate, when first submitted to the General Staff, was cut by them to 10,000, to include all repair facilities, service of supply truck companies, motor truck companies, motor car companies, and motorcycle companies, and on this number, as a basis, the Motor Transport Service in France proceeded to function.

The first order under which the Motor Transport Service was definitely formed, as part of the Quartermaster Corps, was General Order 70, dated December 8, 1917, at G. H. Q., A. E. F. At this time, developments in France had shown that the organization scheme was inadequate and also that the Tables of Organization were unsuitable, and, to correct these conditions, a new estimate of personnel was submitted to G. H. Q. covering overhead, operation and repair. In April, 1918, by General Order 38, War Department, Washington, D. C., the Motor Transport Service was created as part of the Quartermaster Corps in the United States. This was the beginning of the real organization of the Motor Transport Corps. On May 11, 1918, by General Order 74, G. H. Q., A. E. F., the Motor Transport Service was separated from the Quartermaster Corps and placed under the Chief of Utilities. This was a decided step in advance, as it gave much more freedom to the Director of the Motor Transport Service and enabled him to exert a larger influence in promoting efficiency in the corps. About this time it was decided that the Motor Transport Service in France should confine itself to service of supply questions solely and leave the operation of motor vehicles belonging to the combat elements in the hands of the

Quartermaster Corps. The estimate of personnel was therefore cut down considerably and a cable was sent to the United States requesting the organization of a separate Motor Transport Corps, giving a total of the enlisted and commissioned personnel desired for the A. E. F. On July 11, 1918, General Order 114, G. H. Q., A. E. F., was issued changing the Motor Transport Service to the Motor Transport Corps. Finally on August 15, 1918, General Order 75 was issued by the War Department, Washington, D. C. This order formed the Motor Transport Corps as a separate and distinct staff corps and in addition to approving the project submitted by the A. E. F. provided personnel for the United States, Alaska, Hawaiian Islands, Philippine Islands and all other insular possessions. It, however, stated specifically that the Motor Transport Corps was organized merely for the existing emergency. As yet no legislation has been passed making it a permanent branch of the United States Army.¹

The Motor Transport Corps is charged with three main duties. First, the supply, repair, upkeep and furnishing of supplies for all motor vehicles, except tanks and tractors; second, the operation of trucks, motor cars, and motorcycles on lines of communication, and in divisional, corps and army supply trains; third, technical supervision of all motor vehicles. With this latter may be included the administration and inspection necessary for the Motor Transport Corps to function properly. In other words, first is maintenance; second, operation; third, administration. In order to enable the first of these, maintenance, to function properly, four kinds of organizations are maintained: Service parks, overhaul parks, reconstruction parks, and supply depots. In the service park minor repairs are made. It performs repairs of a nature too extensive for company mechanics but not enough so to send the vehicle to an overhaul park.²

There are three kinds of operation units, viz: motorcycle companies, motor transport companies, and headquarters motor commands. The numbers composing each are shown in the Tables of Organization, both peace strength and war strength.

The motor transport company is a combination of the old motor truck company and motor car company. No need was found for different organizations to drive cars and trucks. Provided there was only enough work for one company, motor truck drivers would drive cars in addition to trucks, and motor-car drivers would drive trucks in addition to cars. Another reason is that a great deal of the work was convoy work from base ports and drivers would drive trucks one week and cars the next week.

In the organization and operation of the Motor Transport Corps in France, every advantage was taken of the experience of the British and French armies. From the former, valuable lessons were learned as to the discipline of drivers and the care to be given vehicles to maintain them in an efficient and presentable condition. From the French, lessons were learned as to the most efficient

¹ The lecturer should here refer to General Order 75, War Department, 1918, and read and explain same to the class.

² The lecturer should here explain the latest tables of organization for the Motor Transport Corps and the three classes of repair parks: service, overhaul, and reconstruction.

methods of operating motor transportation in the field, the control of motor transportation on the roads, and economical use of motor vehicles. From that army, also, the principle of pooling vehicles was learned, a principle simple and self-evident in itself and now responsible for most extensive savings and economy. It is, simply, that as few vehicles as possible shall be assigned for specific purposes or to individuals, but that in every locality and with each command, all vehicles shall be pooled and assigned to their work in a manner largely similar to the ordering of a car from a commercial garage. We also learned from the French the capabilities of motor transportation in the transporting of troops. All are familiar with the classic application of this principle at the first battle of the Marne. This principle has added immensely to the mobility of troops and exercises an important effect on tactics and strategy. Motor transport has also shown its capacity for transporting artillery and small tanks. The mobility and speed of the former being greatly increased over that to be obtained by their own horses. The wagons and horses are loaded into the trucks and a speed obtained far greater than the horses themselves could provide. The French army also used trucks for transporting their small tanks. Although these tanks weighed 7 tons, by reinforcing and supporting the springs of the truck, they were transported on 5-ton trucks and an unexpected mobility given to these cumbersome and slow implements.

It is believed that the foregoing will give a fair idea of the history, organization, and functions of the Motor Transport Corps, but before closing a few words should be said as to the importance and value of its work during the war. To the Motor Transport Corps belongs the distinction of having had the first organized units of the American Army to participate in their full war duties on the battle fields of the World War. Four provisional motor transport companies were organized from American volunteers serving with the French Army on Oct. 1, 1917, at Soissons, France, and participated in the operations of Chemin Des Dames Oct. 23 to 30, 1917, which culminated in the battle of Fort Malmaison. It also rushed troops to the aid of the British when the Germans made their attack at Cambrai in the latter part of November, 1917. This command was later increased to over 20 companies, or a total of nearly 1,300 men, and served continually with the French Army until May, 1919, when it was finally returned to the United States for discharge. It participated in 10 of the major operations of the allied armies during the year 1918. Many of its members were awarded the Croix de Guerre for their valiant service, and the command was repeatedly praised by the French Army for its valor and efficiency.

The efficiency of the Motor Transport Corps in France, in spite of its serious handicaps, was recognized by the commander in chief of the American Expeditionary Forces in his awarding to the Director of the Motor Transport Corps and all of his senior assistants the Distinguished Service Medal, in addition to making numerous individual citations throughout the Corps. What General Pershing, the commander-in-chief of the American Expeditionary forces, thought of the Motor Transport Corps is shown in the following letter:

AMERICAN EXPEDITIONARY FORCES,
Office of the Commander-in-Chief, March 2, 1919.

Brig. Gen. MERIWETHER L. WALKER,
Director Motor Transport Corps, A. E. F., Tours.

MY DEAR GENERAL WALKER: At this time, when many officers and enlisted men are returning home and severing their connection with the American Expeditionary Forces, I am glad to take the opportunity of expressing to you, and the officers and men under you, my appreciation and thanks for what the Motor Transport Corps has accomplished.

When war was declared, motor transportation was almost non-existent in the Army. From the outset, the Motor Transport Corps had to meet the most difficult conditions, including its organization, at a time when the demand for motor transportation at the front was greatest; it always suffered from a deficiency of at least 70 per cent in required personnel and of 50 per cent in needed material. The handling of many different types of motors which had been ordered and shipped to France by the various services, combined with an entire inadequacy of spare parts, was another difficulty that had to be overcome.

That the Motor Transport Corps was able to operate, despite these handicaps, and to keep enough vehicles running at the front to supply the fighting troops speaks well for the energy and perseverance of your officers and men. Under all conditions of weather, on bad roads, often under heavy fire, at the front, and throughout France, they labored cheerfully. Your well-considered plans would have soon borne fruit and resulted in a highly efficient service.

In ending I can not neglect the opportunity of thanking you personally for the energetic effort and enthusiasm you have displayed in your difficult task and which produced such fine results.

Sincerely, yours,

JOHN J. PERSHING.

FIELD OPERATIONS.

LECTURE II.

THE MOTOR TRANSPORT COMPANY.

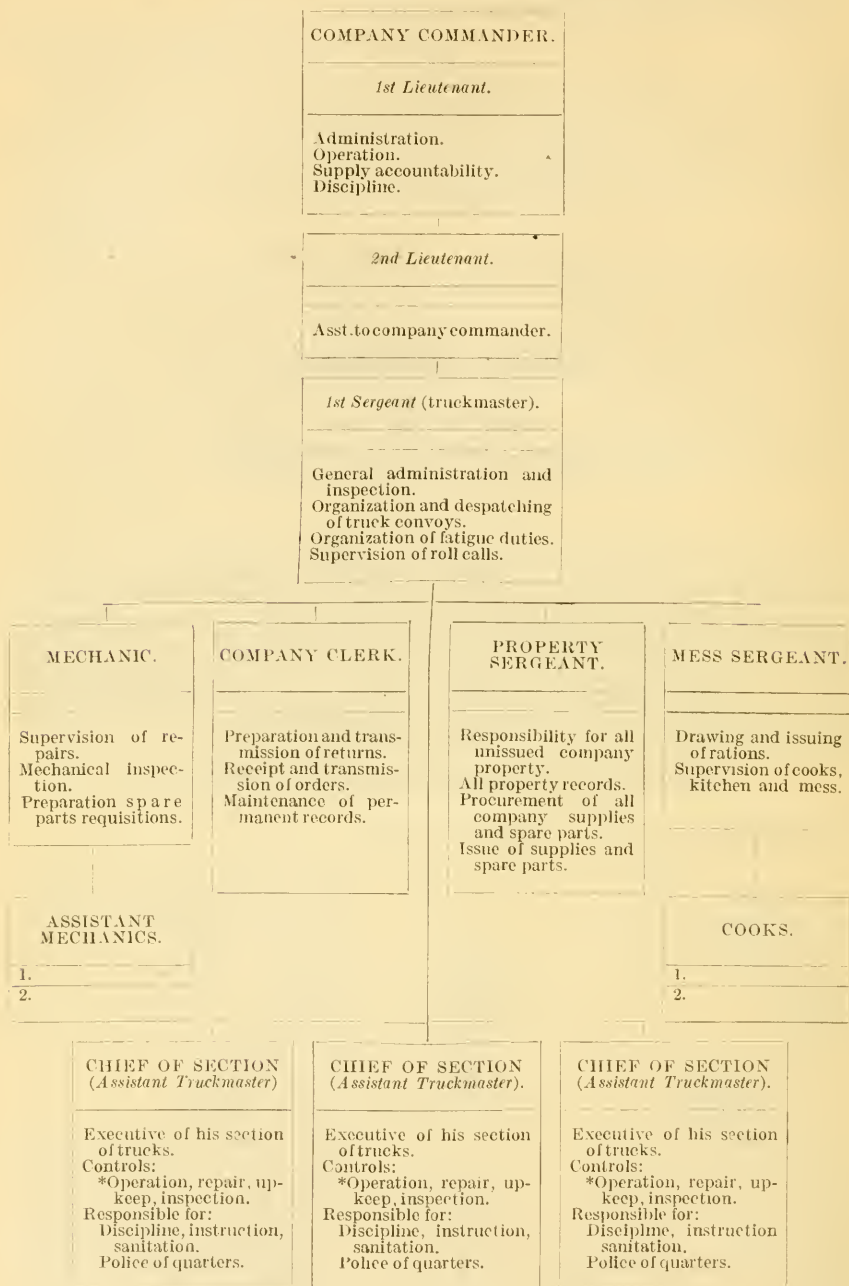
The motor transport company is normally organized into three sections of nine trucks, each section under command of an assistant truckmaster. The service trucks, i. e., tank trucks, etc., are usually kept under the immediate orders of the truckmaster, as they do not form an integral part of the cargo sections. When the company is not operating in convoy, the service trucks may be assigned to cargo work, and in such cases should be attached to sections.

ORGANIZATION OF MOTOR TRANSPORT COMPANY.

(War strength.)

UNITS.		
1st lieutenant	1	b. 1 clerk, 3 chiefs or sections (assistant truckmasters); 1 mess sergeant; 1 property sergeant; and 1 mechanic.
2nd lieutenant	1	
Total commissioned	2	c. 2 assistant mechanics and 32 drivers.
1st sergeant	a1p	d. 9 assistant drivers and 1 messenger.
Sergeants	b7-1pCr	e. Assistant driver.
Corporals	er34	p. Armed with pistol.
Cooks	2r	r. Armed with rifle.
Privates	er24	s. Class A or Class B.
Total enlisted	78	tc. 1 Truck, light repair and truck for company supplies (Class AA).
Aggregate	80	NOTE: If company is partially or fully equipped with passenger cars instead of truck substitute 2 passenger cars for each cargo truck of Class A or Class B.
Privates, 1st class	dr10	NOTE. Class AA is $\frac{1}{2}$ -ton truck.
Cars, motor, light open,		Class A is $\frac{1}{4}$ -ton truck.
5-passenger	1	Class B is 3-ton or over truck.
Motorecycle with side car	1	
Trucks, cargo	v27	
Trucks, cargo	w2	
Trucks, tank	2	
Kitchen, rolling, trailmobile	1	
Pistols	4	
Rifles	76	
REMARKS.		
a. Truckmaster.		

MOTOR TRANSPORT COMPANY ORGANIZATION.



*Includes responsibility for drawing gasoline, oil, and grease.

DUTIES AND RESPONSIBILITIES.

Company commander.—He is responsible for the efficient operation, maintenance, and discipline of his company. He must constantly bear in mind that the value of his organization is measured by the efficiency with which it operates, and by its ability to cope with emergencies.

Second lieutenant.—This officer is the direct assistant of the company commander, and has such duties and responsibilities as are given him by the company commander.

First sergeant.—He is the truckmaster and the executive of the company. He sees that all orders, regulations, and other requirements are properly carried out; that the men perform their duties properly; and reports to the company commander any cases of neglect or violation of orders requiring disciplinary action. He should be a man chosen more for his administrative and executive ability and his efficiency in handling men than for his mechanical knowledge. The mechanic may well be chosen for his ability as a mechanic, irrespective of his ability to handle men, but the first sergeant should be a man of force, as his prime duty is to maintain discipline for the efficient operation of the company.

Mechanic and assistant mechanics.—The mechanic and assistants are under the direct control of the first sergeant. The mechanic should be held responsible for the necessary repairs made to the mechanical equipment of the company. He is in charge of the repair truck, tools and equipment pertaining thereto. He should sign for the tool equipment and issue it to the assistant mechanics on proper receipts. He should be held responsible for this equipment, see that it is properly maintained and that any shortages by damage, loss, etc., are properly made up. Normally, he should see that the assistant mechanics are properly qualified, and should instruct them in their work. In order to perform their duties properly, the mechanic and assistant mechanics should be thoroughly familiar with the instruction books issued by the makers of the vehicles furnished to the company.

The duties of these men will be taken up further under operations and maintenance.

Company clerk.—Has charge of all records, reports, and correspondence of the company. He notifies members of the company as to orders and instructions received, calls upon them for the rendering of prescribed reports, and in consideration of other incidents where he must exercise authority, he has the rank of sergeant. Other duties for him are prescribed by the company commander according to local conditions.

Property sergeant.—Is responsible for all supplies and equipment not actually issued to individuals, and keeps the necessary records therefor. He is responsible, moreover, that all issues of property are properly receipted for by the persons responsible. He keeps the property under his charge clean and in proper order, and should have a list up to date of all property and its disposition. All dealings with the quartermaster or supply officer, not requiring the personal intervention of the company commander, should be carried on by him.

Mess sergeant.—Has direct charge of the mess hall, kitchen, and all matters pertaining thereto, including supervision of the cooks or

other men working in the kitchen. Draws the rations, sees that they are economically used, makes up bills of fare, sees that the kitchen, mess hall, and premises are clean and sanitary, and that all orders in reference thereto are properly carried out. His authority to contract debts, or expend money should be carefully watched and checked by the company commander personally. In some cases, the duties of mess sergeant are performed by the property sergeant, but this depends on the special aptitude of the man, as well as on other local conditions in the company.

Chiefs of sections.—Each chief of section (assistant truckmaster) is responsible for the discipline, instruction, and all other matters pertaining to the personnel of his section; for the operation, repair, and upkeep of the equipment assigned thereto. He is the intermediary between the men of his section and the truckmaster or company commander. His supervision extends to all the details connected with his section, including police and sanitation of quarters, seeing that his men are provided with the necessary equipment and clothing. All orders for his section, either regarding the members of his personnel or the units of his equipment, should be given through him. He should assure himself that his section is in proper condition at all times by making frequent and systematic inspections of his men and equipment. He should examine all his vehicles on their return from work, and see that the drivers have taken proper care of them and that the proper repairs are made. In his absence, for any cause, a suitable man should be designated to perform his duties. His duties will be taken up further in lectures on field work.

Driver.—He keeps his vehicle and its equipment clean and in proper repair and working order. In order to do this he utilizes his spare time while not on duty to do the minor work required thereon. He should be especially required to attend to the proper lubrication of all parts and truck mechanism, and to report promptly any defect noted or repair needed. In transporting material or supplies, he will see that the vehicle is not overloaded, that the cargo is properly loaded and lashed, and ordinarily he is responsible for its safe delivery. He should be familiar with the mechanism of his vehicle and its proper operation, and for this purpose he should be thoroughly familiar with the contents of the instruction book issued by the makers of the vehicle. He should be required to wear proper uniform when driving. His duties will be taken up further in the lectures on field work.

POLICY AND ATTITUDE OF COMPANY COMMANDER.

The company commander should endeavor to standardize, in writing if possible, all important elements of company procedure. Unless all duties and functions are clean cut and clearly defined, a motor transport company, owing to the nature of its work, will become out of control and inefficient.

The development of company spirit, or esprit de corps, must be fostered in every way possible by the company commander. No one factor can be of more value in maintaining good discipline in camp and on the road. The men should be neat in their personal appearance and their vehicles at all times clean. Men can be led to

take great pride in their trucks and in their work. The development of esprit de corps must necessarily rest very largely upon the personality of the company commander and the spirit which he instills into his noncommissioned officers and men.

GENERAL REGULATIONS.

The company commander should use the following as a guide for regulations which will be drawn up by him and posted for the company, in addition to War Department, department and post or camp orders:

Order forbidding introduction of intoxicating liquors.

Order against gambling.

Rules for sanitation to fit the given situation, especially as to latrines.

Pecuniary responsibility of men for loss or damage to any equipment whatsoever, which is clearly due to negligence or carelessness.

The rules of military courtesy briefly outlined.

Establish definitely the limits of the camp.

Impress upon the men the danger and prevalence of venereal disease and outline to them general orders on the subject. Post rules regarding reporting for prophylactic treatment.

Post necessary fire regulations for quarters, kitchen, and trucks (particularly the handling of gasoline).

Establish guard rules.

Inspections of quarters, kitchen, personal equipment, and vehicles should be carefully and regularly made. Inspection under arms should be held weekly, preferably on Saturdays and muster days in the manner prescribed in Infantry Drill Regulations, followed by an inspection of vehicles.

SUGGESTED DAILY SCHEDULE IN CAMP.

6 a. m. Reveille.

6.15 a. m. Roll call, followed by short setting-up exercise.

7 a. m. Breakfast.

7.30 a. m. Camp police.

8 a. m. Morning reports in, and sick call.

8 a. m. Camp inspection; formal on Saturday, informal on other days.

8.15 a. m. Drill and instruction (military and technical).

9.30 a. m. Work on trucks; fatigue.

12 noon. Dinner.

1 p. m. Work on trucks; fatigue, and instruction (military and technical).

5.30 p. m. Supper.

6 p. m. Town leave.

9 p. m. Taps.

THE MOTORCYCLE COMPANY.

The general scheme of organization and administration of a motorcycle company is identical with that of a motor transport company. The details of organization are:

ORGANIZATION OF MOTORCYCLE COMPANY.

(War strength.)

UNITS.		REMARKS.
1st Lieutenant -----	1	<i>a.</i> Cycle-master.
2d Lieutenant -----	1	<i>b.</i> 1 mess and supply sergeant, 1 mechanic, and 3 assistant cycle-masters.
Total commissioned -----	2	
1st Sergeant -----	alp	<i>c.</i> Clerk.
Sergeants -----	b5p	<i>d.</i> 1 assistant mechanic, 2 drivers, and 27 motorcycle drivers.
Corporal -----	clp	<i>p.</i> Armed with pistol.
Cook -----	1p	<i>r.</i> For company supplies.
Privates, 1st class -----	d30p	
Total Enlisted -----	38	
Aggregate -----	40	
Motorcycles with side cars -----	32	
Trucks, cargo, Class AA -----	w2	
Pistols -----	40	

DUTIES AND RESPONSIBILITIES.

General.—The motorcycles and side cars assigned to a company will be those of the standard makes issued to the Army. The details of equipment vary according to the specific make of motorcycles, and there is no general list of equipment that covers all these types. The specific list, however, will be given in the invoices or other record of property furnished the company commander when he receives the motorcycles assigned to his company. In addition to this invoice, he should procure the printed publications issued by the manufacturer of the motorcycles which ordinarily include detailed instructions as to their care, operation, and upkeep, and a parts list, giving the serial or manufacturer's number of each part.

In each company, the division of responsibility with reference to operation, repair, and upkeep of the mechanical equipment should be established by the company commander, and published in a company order, so that each member of the company shall be thoroughly familiar therewith.

The general practice is to make each motorcycle driver responsible for the operation, care, and upkeep of his motorcycle and equipment, as well as all other property assigned him. The extent of the repairs that the drivers should be required to make depends much upon their ability and training. In general, however, this will extend to what are classed as minor repairs, not requiring an extensive mechanical knowledge. Work on the motor, ignition and electric lighting system, or on the interior mechanism of running parts should normally be done under the direct supervision and orders of the mechanic. Aside from this it is better for the chief of section to determine the proficiency of the individual driver before permitting any repair, except the most simple, to be performed by him.

The motorcycles of each section are under the direct supervision of the assistant cyclemaster (chief of the section), who is held responsible for their upkeep and repairs. Likewise, the mechanic, with the assistant mechanic, has general supervision over the mechanism of the motorcycle equipment, as well as the detailed repair work devolving on them.

Duties of assistant cyclemaster.—Each assistant cyclemaster is responsible for the discipline, instruction, and all other matters per-

taining to the personnel of his section; and for the operation, repair, and upkeep of the equipment assigned thereto. He is the intermediary between the men of his section and the cyclenmaster or company commander. His supervision extends to all details connected with his section, including police and sanitation of quarters, seeing that his men are provided with the necessary equipment, clothing, etc. All orders for his section should be given through him. He should assure himself that his section is in proper condition at all times by making frequent and systematic inspections of his men and equipment. He should examine all his motorcycles on their return from work, and see that the drivers have taken proper care of them, and that the proper repairs are made. In his absence, for any cause, an acting chief of section should be designated to perform his duties.

Duties of the mechanic and assistant mechanic.—The practice in reference to mechanics varies in different companies according to local circumstances. The two general systems are (1) the mechanic and assistant mechanic are under the direct control of the cycle master and are not assigned to a given section; (2) the mechanic and assistant mechanic are assigned to sections, and each comes under the control of the corresponding chief of section. In either case, however, the mechanic should be held generally responsible that proper repairs are made. He is in charge of the repair and tool equipment pertaining to the organization. He should sign for the tool equipment and issue it to the assistant mechanic on proper receipts. He should be held responsible that this equipment is properly kept up, and that any shortages by damage, loss, etc., are properly made up. Normally, he should see that the assistant mechanic is properly qualified and should instruct him in his work. In order to perform properly their duties, the mechanic and assistant mechanic should be thoroughly familiar with the instruction book issued by the maker of the machines furnished the company.

Duties of driver.—He keeps his motor cycle and its equipment clean and in proper repair and working order. In order to do this, he utilizes his spare time while not on duty to do the minor work required thereon. He should be especially required to attend to the proper lubrication of all parts of the motor-cycle mechanism, and to report promptly any defect noted or repair needed. Operators are cautioned against overloading a motor cycle or side car. The maximum weight to be carried by a solo motor cycle is 300 pounds. The maximum for a motor cycle and side car combination is 450 pounds. These weights apply to the twin-cylinder, three-speed motor cycles now in use. The driver should be familiar with the mechanism of his machine and its proper operation, and for this purpose he should thoroughly study the contents of the instruction book issued by the maker. The driver should be required to wear the proper uniform when driving.

Routine.—The following is a brief account of the daily routine of a company engaged in work at a depot or permanent camp. The regular reveille and breakfast should be had at the hours prescribed for the command in general. After reveille, the tents or quarters should be properly arranged, bunks made up, etc. This is followed by military and technical instruction and drill under the company officers and noncommissioned officers.

When a machine returns to the company park, after the day's run, it should be gone over by the driver, under supervision of the assistant cycle master, and be put in shape for immediate work if ordered out. This includes the filling of gasoline tanks, replenishment of lubricating material, filling lamps, if they use oil, and in making all repairs and adjustments. The invariable rule should be that all motor cycles in the park are always ready to make a day's run.

Motor-cycle company commanders can not be too careful of the grade of oil used. Never allow a tank to be filled with automobile oil unless in an emergency when motor-cycle oil can not be obtained. In case auto oil has to be used, frequent use of the hand pump is necessary. Motor-cycle oil for summer use should be Mobile B; and in winter Mobile BB; or during extreme cold weather, Mobile A or oils of like viscosity and flash test.

The issuing of gasoline and other supplies is done under the immediate supervision of the man detailed therefor. Precautions to be taken against fire should be given in the form of "Fire Orders" prepared by the company commander.

On returning to the company park, the drivers turn in the written order, if one was given, that sent them to work, and at the same time complete their daily reports and turn them into the company office.

The other routine work is carried on according to circumstances that vary so greatly that more definite description thereof would be without profit.

The general regulations in addition to War Department, department, and post or camp orders will be followed the same as in motor transport companies.

FIELD OPERATIONS.

LECTURE III.

GENERAL PRINCIPLES OF CONVOY.

Two or more trucks operating together constitute a convoy. When 10 or more trucks are so used, they are divided into sections, each section being in charge of a noncommissioned officer.

A truck company is composed of 27 cargo trucks, divided into 3 sections of 9 trucks each. Attached to the company is a light repair truck, which is placed as a file closer at the end of the third section: each company also has 2 tank trucks, a supply or commissary truck and a kitchen trailmobile. These latter do not as a rule travel with the convoy, but are dispatched to a predetermined camping or refilling point.

Convoys are used to transport (*a*) troops, (*b*) materials and supplies.

TYPES OF CONVOYS.

There are three types of convoys: (1) A company or part of a company. (2) Two or more companies operating together in a train. (3) Group convoy, which consists of several trains operating together at times amounting to several thousand trucks. This type is not ordinarily used, except when large numbers of troops are to be moved. Troops are usually transported in group convoys. In handling group convoys the following important principles should govern.

RELATION TO INFANTRY ORGANIZATION.

It may prove of assistance to the student to note the similarity existing between his infantry training and that of his Motor Transport work. Just as the school of the soldier is first taught in infantry work, so is the handling of a truck taught in motor transport work. The section and handling of a section correspond to that of a platoon of infantry. The truck company corresponds to a company of infantry and the motor transport train (two or more companies) corresponds to a battalion.

The duties of the commanding officer are many and varied. Upon him devolves the responsibility for the efficiency of the entire unit. If he is lax in discipline, and indifferent to the care and upkeep of his equipment, his attitude will be reflected by the entire command.

A few of the duties of the commanding officer are enumerated, in order to give a general idea as to what is expected of him. It is his duty to choose and instruct competent noncommissioned officers to assist him in his work. He must see that all of the rules and regulations of the Army, and of the Motor Transport Corps are observed, and that any man who violates these rules is properly dealt with. Before starting on a convoy, the commanding officer will be sure that the supply of gasoline is adequate for the trip; that rations and clothing for the men are sufficient; that proper road repair facilities are provided, and that the cargo has been properly loaded. While preparations are being made to leave, he should devote his time to inspecting the company, observing each truck, each man, and seeing that everything needed has been loaded, taking into consideration the length of time they will be on convoy and when and where they will be able to procure more supplies. He will also provide himself with necessary maps, passes and orders. When the company is halted, the commanding officer will see that the drivers and assistant drivers do whatever is necessary to prepare their vehicles for an immediate start. It is of the utmost importance that the men should prepare their equipment to resume a trip at a moment's notice, before they are dismissed and allowed to seek their quarters. It is a great temptation at the end of a long hard day to slight this particular phase of the work, making the excuse that they will do the necessary cleaning and refilling in the morning before starting. The result of such a practice is that many things are left undone. The last thing the company commander should do for the day is to make an informal inspection of his equipment and see that gas lines are shut off, seats turned up, and in case of cold weather, that radiators have been drained. At times the company commander will find it unnecessary to accompany the convoy, as in some cases the company will be split; part of the organization going to one place and part of it in a different direction. Under such circumstances it is for him to decide which convoy is the more important, and to accompany that part. He should then send his second in command, or his truckmaster, and assistant truckmasters, with the other sections. If a company is so divided that the number of assistant truckmasters is not sufficient to accompany each convoy, he will appoint one of his best drivers to take charge of the remaining trucks. Only when the company is split into small convoys should the company commander send the company out under the truckmaster, or assistants. His place is in active command, and he should be with the company at all possible times. His position usually is in the rear of the company; he should, nevertheless, pass the convoy as often as is necessary to assure himself that the column is operating properly. He should be on the watch for all trucks compelled to drop out for repairs, and give the necessary instructions regarding them. When operating through unfamiliar territory he should precede his convoy. On entering strange towns, he should go ahead and make whatever arrangements may be necessary to pass through the city, village, or large town, and acquaint himself with road conditions, traffic rules, etc., leaving instructions with his truckmaster as to where he desires to have the convoy halted until he rejoins the company. When the

company commander is traveling in the rear of his company, the truckmaster who is riding in the first truck of the first section will act as guide. All railroad crossings and strange bridges should be examined before the arrival of the company, and if necessary, a man should be stationed there to transmit all orders, and in case of danger, to halt the convoy. In the case of bridges, this guide should indicate to the drivers the number of trucks to be allowed upon the bridge at one time. In case it becomes necessary to split a convoy, it is best to do so at the end of a section. The assistant truckmaster, or driver, acting as a guide should be picked up by the last truck in the company. The commanding officer is responsible for all his equipment. He should therefore avoid as far as possible permitting the vehicles under his command to proceed on soft ground with consequent danger to the vehicles, etc. When it becomes necessary to pitch a new camp, as in the case of a long convoy, the commanding officer must determine the camping ground most suitable for the men, and also must select a suitable parking space for the trucks.

DUTIES OF THE TRUCKMASTER.

The truckmaster holds the position next in importance to the commissioned personnel. He is the first sergeant, and is therefore the immediate executive. He dispatches all truck convoys, under directions of the commanding officer; he attends to all calls, such as fatigue details, roll calls, etc. He transmits all orders and directions of the commanding officer, and is directly responsible to him. He reports to the commanding officer any cases of neglect or violation of orders requiring disciplinary action. On convoys he is usually the guide.

DUTIES OF THE ASSISTANT TRUCKMASTER.

At all times the assistant truckmaster is the chief of his particular section. He is to his section what the truckmaster is to the company. He is the intermediary between his men and the first sergeant. All orders for the drivers should go through the assistant truckmaster. He should work with the assistant mechanic on informal inspections, making sure that his section is always in good condition and ready to move at any time.

DUTIES OF THE PROPERTY SERGEANT.

The property sergeant is responsible for all supplies and equipment not actually issued to individuals, and will keep the necessary records therefor. He should see that all issues of property are properly receipted for by the persons responsible, should keep the property under his charge clean and in order, and he should have the list up to date of all company property and its disposition. All dealings with the quartermaster or supply officer not requiring personal supervision of the company commander should be carried on by the property sergeant.

DUTIES OF THE MESS SERGEANT.

The mess sergeant has direct charge of the mess, mess hall, kitchen, and all matters pertaining thereto, including the supervision of the cooks or other men working in the kitchen. He draws the rations, sees that they are economically used, makes up bills of fare, sees that the kitchen, mess hall and premises are kept clean and sanitary, and that all orders relating thereto are properly carried out. His authority to contract debts or expend money should be watched and checked by the company commander personally.

DUTIES OF THE MECHANIC.

The mechanic is a sergeant and the assistant mechanics corporals. The mechanic is responsible for the mechanical condition of the vehicles of the company. It is his duty to see that the assistant mechanics properly perform their work, and also to oversee all important repairs. He receipts for the equipment of the repair truck and for tools and small parts. The assistant mechanics are usually assigned to different sections, but work under the direction of the mechanic. On convoys he is usually the file closer.

DUTIES OF THE DRIVER.

The driver is assigned to a truck and remains with that truck, unless transferred under orders of the commanding officer. Every truck is equipped with a complete set of necessary tools, for which the driver is responsible and for which he signs. This equipment is subject to inspection any time, and it is the driver's duty to see that everything for which he is responsible is ready for inspection at all times. He should spend all possible time on the vehicle, keeping it in first-class condition and making all minor adjustments. A great deal of time may be saved by a driver if he will attend to the little details of the upkeep of a truck during the time that he may be held up, waiting for a load, or when the convoy is delayed on the road. By cleaning his truck a little at a time during these waits, he will find that when formal inspection comes it will be very much easier for him to be prepared than if he had left it until the time allowed for inspection arrived. The driver is also responsible for the safe delivery of the cargo and for the manner in which his truck is loaded. He will not be required to assist in loading trucks, but he should see that his truck is not overloaded at any time. The assistant driver works under the direction of the driver, taking orders from him and assisting him in every possible way.

PARKING.

In selecting a permanent parking place for motor vehicles particular attention should be paid to the condition of the ground, the drainage and the amount of available space. Cinders or crushed rock should be employed in a permanent park. In order that proper alignment may be established, sighting posts may be planted at either

end of the line of trucks. All trucks will be aligned so that the caps of the radiators will be in line with the sighting posts. It is the duty of the assistant truckmaster to see that all trucks in his section are properly aligned at all times while they are parked.

The following are the usual methods of parking.

COMPANY FRONT.

All the trucks of the company are lined up side by side. The interval between trucks should be 2 yards; between sections 4 yards. This formation is best if the space is available.

COLUMN OF SECTIONS.

Trucks arranged in column of sections are spaced at 2-yard intervals between trucks, and a distance of 7 yards between sections.

LINE OF SECTIONS.

In line of sections the trucks of each section are in column, sections and corresponding trucks of sections being abreast. The interval between trucks of a section is 2 yards. The interval between sections is 7 yards. The staff car is 2 yards to the right of the first truck of the first section, front wheel hubs in line. The supply truck, with kitchen trailmobile, is 2 yards to the left of the first truck of the third section, front wheel hubs in line. Tank truck No. 1 is 2 yards to the left of the third truck of the third section, front wheel hubs in line. Tank truck No. 2 is 2 yards to the left of the fourth truck of the third section, front wheel hubs in line. The repair truck is 2 yards to the left of the fifth truck of the third section, front wheel hubs in line.

DISTANCES AND SPEEDS.

When trucks are operating in convoy formation, it is necessary that there be certain assigned distances and speeds. There are two formations for moving convoys, known as "open" and "closed," the open formation being used on the highways and the closed formation in villages, cities, or densely populated countries of any kind.

Assigned distances for trucks.

	Open formation.		Closed formation.	
	Yards.	Lengths	Yards.	Lengths.
Between vehicles.....	20	3	7	1
Between sections.....	40	6	20	3
Between companies.....	80	12	40	6
Between trains.....	100	15	60	9

When halted, vehicles will close up to 5 yards and sections to 20 yards.

Speeds to be maintained.

	In towns (miles per hour).	Outside of towns (miles per hour).
Trucks, Class A.A.	12	20
Trucks, Class A.	12	15
Trucks, Class B.	8	14
Ambulances.	12	18
Light delivery vehicles 3-4 ton capacity or less. Examples: Ford and Dodge light trucks.	12	20
Small passenger vehicles. Examples: Ford and Dodge touring cars, roadster, and closed cars.	15	25
Motorcycles without side cars.	18	35
Motorcycles with side cars.	18	30
Heavy passenger vehicles. Examples: Cadillac, Packard.	18	35

Local speed regulations will not be exceeded.

The great fault with the average driver in convoy work is the tendency to overspeed, and particular stress should be laid upon this point. The disadvantages of overspeeding are many, the two important ones being the destruction of roads and equipment and the inevitable accidents which will occur. It should be the aim of the motor truck company at all times to deliver cargoes in the same good order in which they were taken. In modern warfare, with the limited traffic facilities, the large number of vehicles of all description, and for all sorts of purposes in use, results in congestion of the roads, thereby causing delays in transportation, so that the problem of delay rests more upon careful handling than upon speed. Under normal conditions it may be interesting to note that the average speed of trucks, figured over a daily run, is 75 per cent of the governed speed. The Army truck will do better at 50 per cent of the governed speed.

METHODS OF KEEPING CONTACT.

When convoying on narrow, winding roads which pass through forests or are so concealed that it is difficult to distinguish objects at any distance in front or rear, contact is kept as illustrated in the following example:

Imagine a convoy traveling on such a road. There is a sharp bend, immediately followed by a fork in the road. The itinerary has been determined in advance by the company commander and the truckmaster knows on his map which road to take. It is necessary for him to lead the convoy. The first truck has arrived at the fork in the road, while the second truck is not yet in sight. If the first truck proceeds the second truck driver will have lost his pathfinder. Therefore, the first truck should slow down or halt long enough to permit the second truck to come in view, and so on through the convoy. The method that causes the least decrease in speed, however, is that of placing a man at the fork to direct trucks of the convoy as they pass. This man is designated by the truckmaster of each company, and as the last truck of the company to which that man is attached passes the fork he boards it, and is succeeded as guide at the fork by a man selected in turn by the truckmaster of the next company, and so on.

CLASSIFICATION AND MARKING.

All motor vehicles are painted with the regular olive-drab paint. The system of classification is as follows:

Passenger cars (regardless of size or body).....	Type 1
Light delivery trucks (1 ton or less capacity)	Type 2
One and one-half and two ton trucks.....	Type 3
Three and four ton trucks.....	Type 4
Five-ton trucks, or over.....	Type 5
Motor cycles with or without side cars.....	Type 6
Motor ambulances (all sizes and makes).....	Type 7
Tractors (except caterpillars).....	Type 8
Caterpillars.....	Type 9
Trailers (cargo).....	Type 0
Machine shop trucks (regardless of repair equipment).....	Type 00
Kitchen trailers.....	Type 10
Omnibus cars.....	Type 20
Balloon winch trucks.....	Type 30
Disinfectors and fire engines.....	Type 50
Laboratories (dental trucks, medical laboratories, photo laboratories, sterilizing trucks, etc.).....	Type 60
Machine shop trailers.....	Type 70
Tank trucks (water and gasoline) and sprinklers.....	Type 80

SYSTEM OF MARKING.

The identification numbers for all motor vehicles will be assigned by the chief, Motor Transport Corps. The identification numbers will be placed on both sides and on the rear of each motor vehicle, the symbols composing such numbers to be 4 inches in height and the complete number to be preceded by the letters "U. S. A." On the truck and ambulances the numbers will be placed on the hoods. On passenger cars on the rear door panels, and on rear of tonneau; on trucks the rear number will be shown on the right two-thirds or two panels of the tail gate, and on other vehicles in the center of the rear. The identification numbers on trailers will be placed on both sides and in the center of the rear of the body in symbols not less than 2 inches in height.

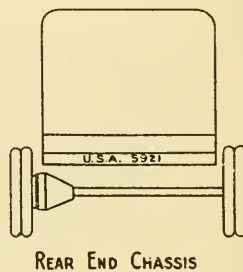
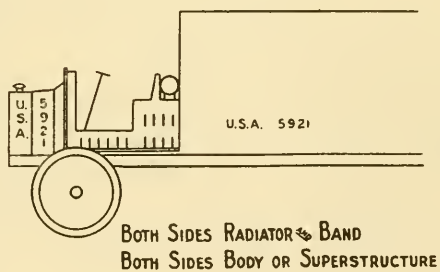
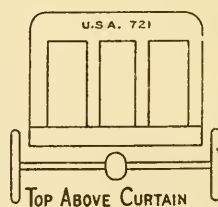
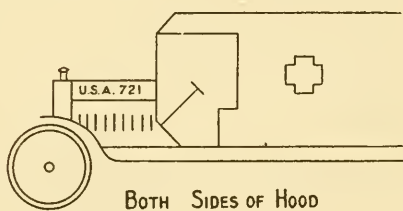
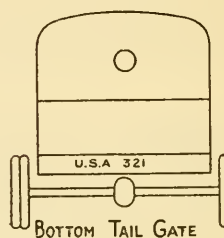
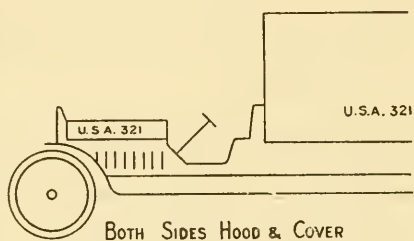
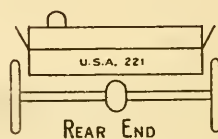
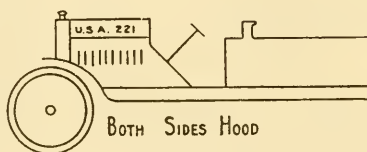
Numbers for motor cycles to which side cars are attached on the right side will be placed on the left side of the gasoline tank of the motorcycle and on the right side, front, and rear of the side car. Symbols on motor cycles and side cars will not be less than 2 inches in height. Side cars are not given separate numbers, but take the number of the motor cycle to which they are attached.

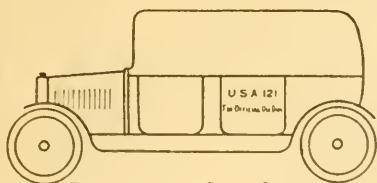
The identification numbers for motor cycles without side cars will be shown on both sides of the gasoline tank, and on the plate attached to the rear mud guard, in symbols not less than 2 inches in height.

On trucks, passenger vehicles, and motor ambulances assigned to ammunition, engineer, supply, and sanitary trains, the identification insignia will be shown on both sides of bodies of vehicles, and in the case of trucks on the left one-third or panel of the tail gate.

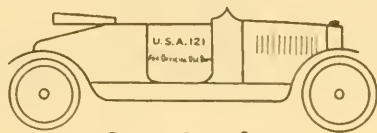
SYSTEM OF NUMBERING.

The first numeral of an identifying number on a motor vehicle will indicate the type of such vehicle. This numeral, together with those making up the complete number, gives the registration num-

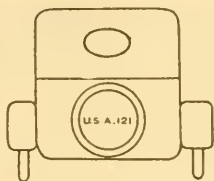




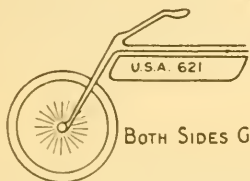
REAR DOORS ON BOTH SIDES



DOORS BOTH SIDES



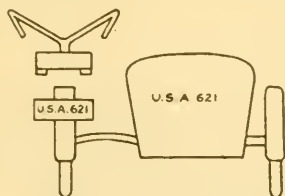
REAR END



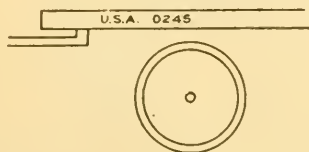
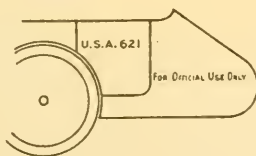
BOTH SIDES GAS TANK



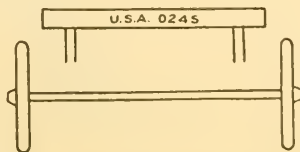
ON MOTOR CYCLE



WITH SIDE CAR



TRAILER SIDE



TRAILER REAR END

ber of the vehicle. Thus, the six hundred and eighty-fifth passenger car placed in service would be type 1-685 or U. S. A. 1685.

A motor vehicle privately owned but operating in the Government service has the usual identification numbers followed by an X.

Further examples are as follows:

Vehicle No. 1, passenger car	U. S. A.	11
Vehicle No. 1, light delivery truck	U. S. A.	21
Vehicle No. 1, 1½-ton truck	U. S. A.	31
Vehicle No. 1, kitchen trailer	U. S. A.	101
Vehicle No. 5, privately owned passenger car	U. S. A.	15X
Vehicle No. 6, privately owned 1½-ton truck	U. S. A.	36X
Vehicle No. 1, privately owned kitchen trailer	U. S. A.	101X

ADDITIONAL MARKING.

In order that the identification number of each motor vehicle may be indelibly shown thereon, such number shall be painted on the right-hand longitudinal member of the frame of the chassis, together with the serial number of each vehicle. These numbers shall be not less than one-half inch in height.

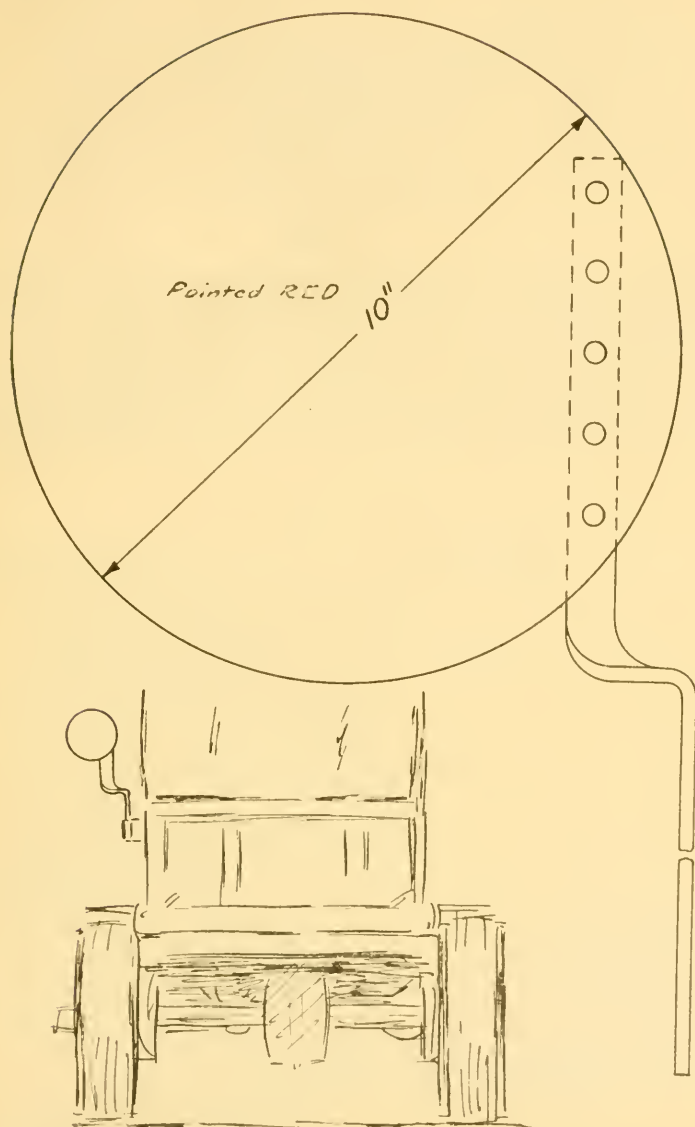
The identification number, once assigned to a motor vehicle, remains with that vehicle during its life, notwithstanding the fact that the motor, or other parts, may be changed. When a vehicle loses its identity through capture, salvage, or other cause the number so vacated will not be reassigned to any other vehicle.

COVERS.

Motor truck covers will be marked with the same identification number as the trucks to which they belong. Such numbers will be placed on the covers so as to make them visible on either side when the cover is in place: symbols to be not less than 4 inches in height.

SECTION MARKINGS.

In order to indicate the last truck of a section a red disc 12 inches in diameter, mounted on a suitable staff, is attached to the rear of the truck, so as to project to the left and be visible from front and rear. The end of the company, or the last truck at the end of the third section, is designated by a double disk in the same way.



Disk used to designate end of sections. Double disk of the same style is used at the end of companies.

FIELD OPERATIONS.

LECTURE IV.

CARE OF EQUIPMENT.

1. Since the entire transportation problem depends upon the condition of the motor equipment, too much stress can not be laid upon the prime importance of keeping this in the best possible shape by means of careful attention and frequent inspections. The difficulty of securing replacement parts when the Army is operating on foreign soil, should serve as a further incentive to the individual driver to conserve the wear and tear on his truck to the best of his ability.

DAILY DUTIES.

Each day the following duties will be performed:

1. Wash truck.
2. Fill crank case to proper level.
3. Oil fan bearing.
4. Grease water pump (use heavy grease).
5. Lubricate starting crank.
6. Grease steering connections.
7. Grease steering knuckles.
8. Lubricate clutch-bearing trunnion.
9. Lubricate clutch-case bearing.
10. Lubricate spring shackles.
11. Lubricate rear-axle brake shaft.
12. Lubricate brake-shoe equalizer pins.

Every 300 to 400 miles:

1. Drain oil from crank case, wash out with kerosene, and refill to proper level.
2. Clean motor and pan under motor, clean spark plugs, clean carbureter.
3. Fill up all grease cups and oil wells and see that oil or grease has clear passage to bearing surface and passages are not plugged up with grit or dirt.
4. Clean oil strainers.
5. Grease wheel bearings on all four wheels.
6. Grease steering-gear case.
7. Oil spark throttle-rod sockets and joints.
8. Oil brake-rod clevises.
9. Lubricate equalizer and intermediate brake bars.
10. Examine clutch and if leather-faced cone clutch apply neats'-foot oil.

Part.	Quantity.	Lubricant.
Fan hub bearing.....	Few drops.....	Motor oil.
Pump shaft grease cups.....	Two complete turns.....	Cup grease.
Steering gear case oiler.....	Fill.....	Motor oil.
Steering gear case grease cup.....	Two complete turns.....	Cup grease.
Steering wheel oil hole.....	8 or 10 drops.....	Motor oil.
Steering column.....	10 or 15 drops.....	Do.
Spark and throttle shafts.....	Few drops.....	Do.
Control bracket bearings.....	Thoroughly.....	Do.
Transmission case.....	Enough to cover lower shaft.....	Transmission grease.
Brake pull rods and connections.....	Thoroughly.....	Motor oil.
Pedal fulcrum pin.....	Do.....	Do.
Brake cross rod grease cups.....	Two complete turns.....	Cup grease.
Torque rod grease cups, front and rear.....	Do.....	Do.
Brake shafts on rear wheels.....	Thoroughly.....	Motor oil.
Rear spring perch grease cups.....	Two complete turns.....	Cup grease.
Magneto bearings (3 oil holes).....	3 or 4 drops.....	High grade light machine oil.
Dynamo drive shaft universal joints.....	Fill one-half full.....	Cup grease.

11. Examine brakes and adjust as may be required.
12. Examine all wiring to see that connections and insulation are in good condition.
13. Go over all nuts and bolts and tighten them if they are loose.
14. Lubricate universal joints.

Every 1,000 to 1,200 miles:

1. Fill transmission to proper level.
2. Fill differential to proper level.
3. Examine all grease boots, clean, and refill.
4. Jack up vehicle and clean and grease springs.
5. Put about two drops of oil on magneto bearing.
6. Put about two drops of oil in generator bearing.
7. Clean all gasoline strainers.

Part.	Quantity.	Lubricant.
Crank case.....	Drain off dirty oil; clean oil screen at left of motor thoroughly; fill to level of top try cock.	Motor oil.
Reach rod boots.....	Pack thoroughly.....	Cup grease.
Spring leaves (jack up frame and pry leaves apart).....	Thoroughly.....	Graphite grease.
Hub caps.....	Pack thoroughly.....	Cup grease.
Universal joints.....	Remove grease hole plug and fill one-half full.	Do.
Gasoline pressure hand pump.....	4 or 5 drops on leather.....	Light machine oil.
Differential housing.....	One-half full.....	Special axle compound.
Transmission case.....	Drain thoroughly, flush with kerosene, refill to cover top lower shaft; try cock.	Transmission grease.

INSPECTIONS.

The inspections that should be held in all Motor Transport Corps formations may be classified as (a) General, and (b) Technical. The first class includes inspection of personnel, quarters, mess, sanitation, camp bivouac (or billet), equipment, and motor vehicles in so far as relates to their cleanliness, completeness, and general upkeep, and are either informal or formal. The second class includes technical inspections of the motor vehicles and their mechanism, to determine

actual mechanical condition and upkeep; these inspections are discussed in Lecture X.

GENERAL INFORMATION.

Informal inspections should be made daily by unit commanders and as often as possible by higher commanders, and should cover quarters, kitchens, messes, etc., as well as vehicles.

Formal inspections are made by company commanders each week where it is practicable to do so, and by higher commanders on stated occasions. The following method of procedure will be carefully followed:

1. The trucks will be thoroughly washed with water, and bodies, tools, boxes, etc., will be cleaned.

2. After washing, a solution of sal soda (two handfuls to a pail of water) may be used for cleaning the grit and grease from the joints, etc. Care must be taken in using this sal soda solution that it does not come in contact with the woodwork, as it will tend to remove the paint. Gasoline or kerosene may be used for the same purpose, but sal soda is less expensive and should be used for economical reasons.

3. All grease cups should be filled and turned down until all the black grease has disappeared, and until clear yellow grease shows on all joints. Do not wipe this grease away, but leave it as an outside coating to protect moving joints, etc.

4. The mechanical part of the truck should then be cleaned in the following order, working from the front of the truck to the rear:

1. Engine (taking out and cleaning spark plugs).
2. Dust pan.
3. Clutch.
4. Short shaft.
5. Steering gear and front axle.
6. Transmission.
7. Propeller shaft.
8. Frame.
9. Springs.
10. Differential.
11. Rear axle.
12. Wheels.

During this part of the cleaning special attention should be devoted to testing bolts and nuts to see that they are not loose, and in case any are missing, a note should be made that they be replaced immediately.

FORMATION AND PREPARATION FOR INSPECTION.

The formation for inspection will be either in line or column of sections. Interval between vehicles, 2 yards; distance between sections, 14 yards. Passenger vehicles on the right of the front line of vehicles.

POSITION OF "PREPARE FOR INSPECTION."

Men will stand at "Attention," driver 1 foot from fender on side of driver's seat and on a line with the front of the radiator; assistant

drivers and mechanics, cooks, and other such personnel in a position corresponding to that of the driver, but on the opposite side of the truck. Assistant truckmaster 1 yard to the right of the right truck of his section and 1 yard in front of the line of drivers. Truckmaster in line on right of flank, and 1 yard from assistant truckmaster. Company commander 1 yard in front of his vehicle. Other company officers on his left.

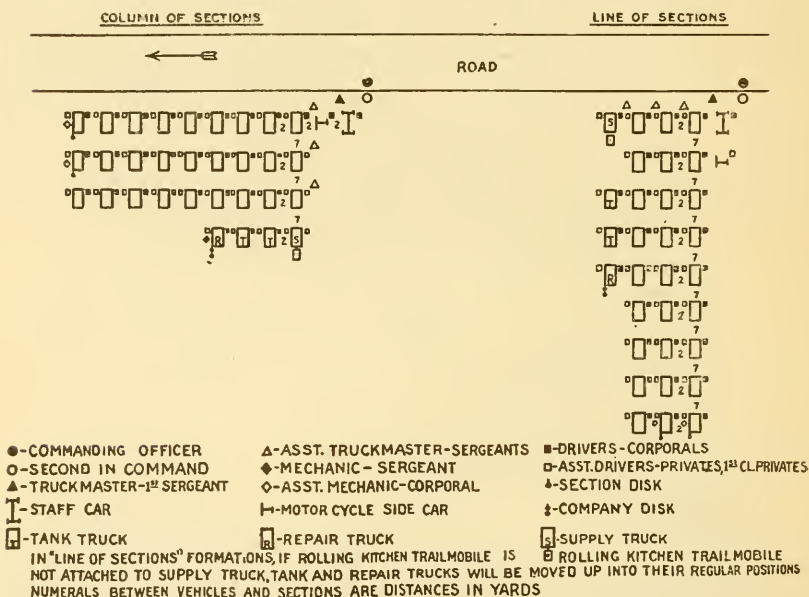
Hoods of all automobiles and trucks will be raised to expose motor. All tool boxes or other such receptacles will be open to show interior. Seat cushions will be raised to expose under side.

All tools, kits, and such truck equipment will be laid out in a

COMPANY FORMATION PREPARATORY TO INSPECTION

POSITION OF OFFICERS N.C.O.'S AND MEN AT COMMAND

LPREPARE FOR INSPECTION 2. ATTENTION



uniform manner on the ground alongside the tool box. Lash ropes, properly coiled, will be hung on front bows on either side of truck. In temporary camp or on the march, articles of personal equipment will be laid out uniformly on shelter half, rear of shelter half 1 yard in front of radiator and in front of each individual. All articles of equipment will be laid out so that stencil markings are plainly visible.

Diagrams indicating a method of laying out equipment will be found in this lecture.

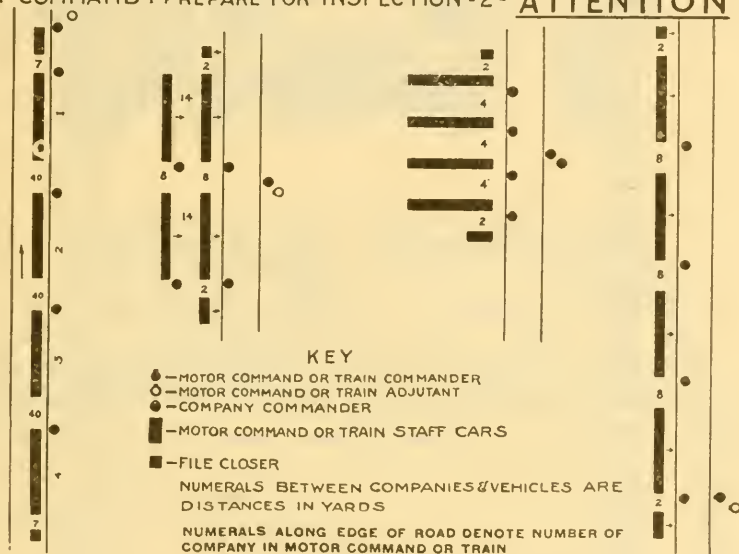
As each vehicle is reached, the commanding officer will check off its number on the list of vehicles belonging to his command or attached thereto, in order to account for all of the vehicles for which he is responsible. Such other vehicles as are still part of the organi-

zation that are not in a serviceable condition, should be subsequently inspected at the repair shop.

The commanding officer will first examine the inspection chart or form covering the individual vehicle for which purpose the inspection report covering technical inspections will be used, and which will have previously been filled out by the truckmaster or mechanic during the technical inspection. The commanding officer will note particularly what provision has been made for the repair or correction of any faults or defects which may have been discovered in such technical inspection, in order to satisfy himself not only that the exact condition of the vehicle is thoroughly known, but that suitable steps have been taken to rectify any unsatisfactory condition. The commanding officer will inspect the driver's log book

MOTOR COMMAND OR TRAIN FORMATION PREPARATORY TO INSPECTION

POSITIONS OF COMMANDING OFFICER, ADJUTANT, AND COMPANY COMMANDERS
AT COMMAND-1-PREPARE FOR INSPECTION-2- **ATTENTION**



to insure that proper entries have been made therein, especially in regard to repair or replacement of a part which may have been made since the original issue of the vehicle.

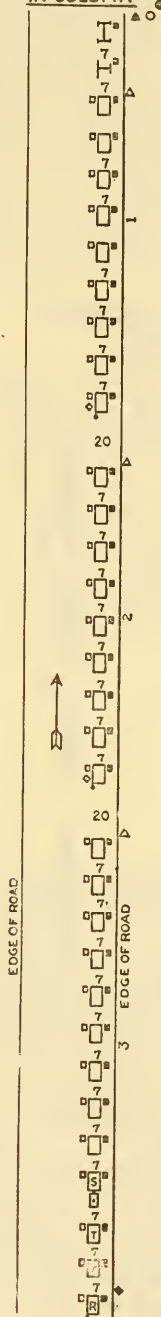
During inspection the commanding officer will hold at "Attention" only the section that he is inspecting; the others will stand at ease until called to "Attention" again.

The commanding officer will require the driver to start the engine and will observe its ease of starting, its quietness in running, its speed control of governor with throttle open and spark advanced, and vibration due to wear in third point suspension, or mounting. The engine will then be stopped by throwing off ignition switch.

Steering connections from steering wheel to road wheels will be inspected for proper adjustment.

COMPANY FORMATION PREPARATORY TO INSPECTION

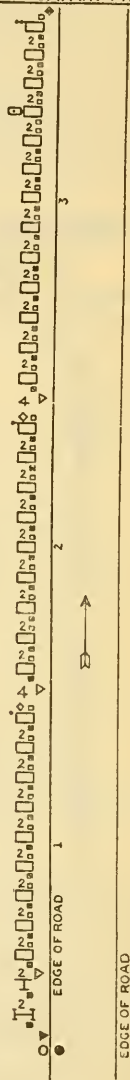
IN COLUMN



POSITION OF OFFICERS N.C.O.'S AND MEN AT COMMAND:

1. PREPARE FOR INSPECTION 2. **ATTENTION-**

IN COMPANY FRONT



-KEY-

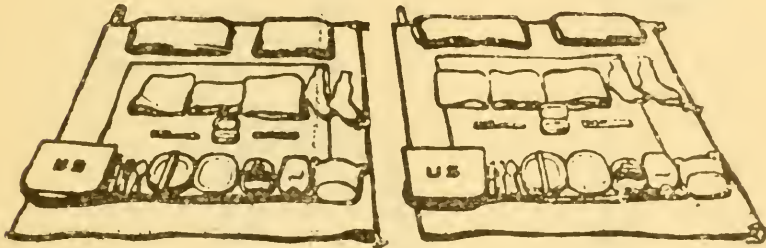
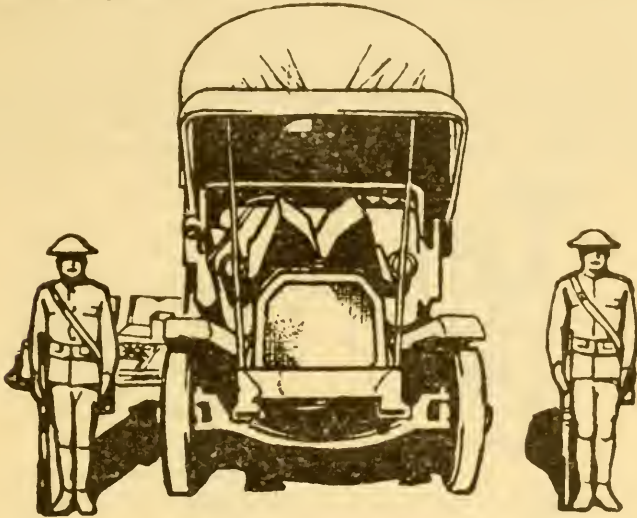
- - COMMANDING OFFICER
- - SECOND IN COMMAND
- ▲ - TRUCKMASTER-1st SERGEANT
- △ - ASST. TRUCKMASTERS-SERGEANTS
- ◆ - MECHANIC - SERGEANT
- ◇ - ASST. MECHANIC - CORPORALS
- - DRIVERS - CORPORALS
- - ASST. DRIVERS-PRIVATES, 1st CL. PRIVATES
- ⬇ - SECTION DISK ⬆ - COMPANY DISK
- ⊞ - STAFF CAR ⊞ - MOTORCYCLE SIDE CAR
- ⊞ - TANK TRUCK ⊞ - REPAIR TRUCK ⊞ - SUPPLY TRUCK

NUMERALS BETWEEN SECTIONS ⊞ ROLLING KITCHEN TRAILMOBILE
 + VEHICLES ARE DISTANCES IN YARDS. ALONG EDGE OF ROAD DENOTE
 POSITION OF SECTION IN COMPANY. ALL DRIVERS BESIDE RIGHT FRONT
 WHEEL HUB. ASSISTANTS BESIDE LEFT FRONT WHEEL HUB.

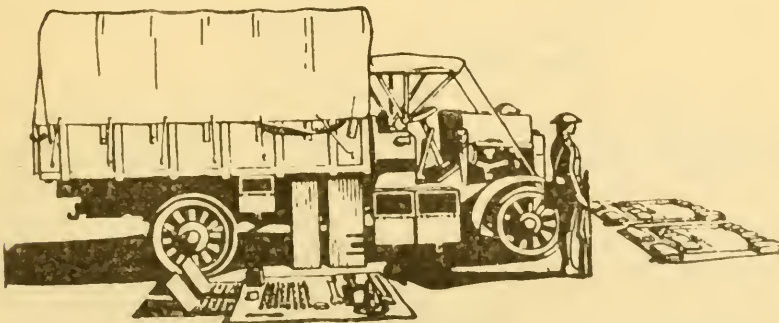
Running gear will be examined for condition and cleanliness.

Brakes will be examined and tested for adjustment.

Tool kit and unit equipment will be inspected for comparison with authorized equipment.



Position of driver and assistant driver for inspection.

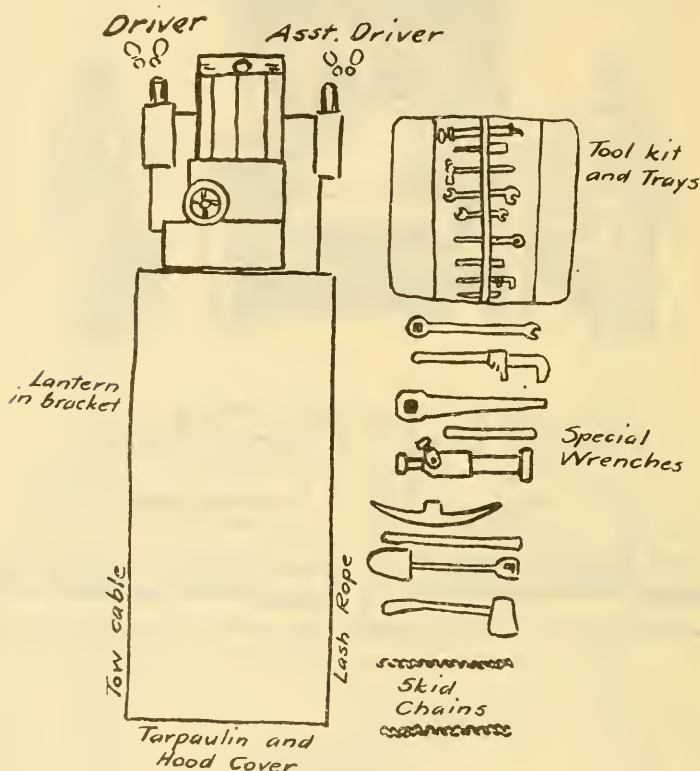


Truck ready for inspection.

While making this general inspection the commanding officer will observe particularly the cleanliness of the mechanical parts of the vehicle, especially at points of lubrication. The least accessible points on the chassis will also be inspected for cleanliness, as loose-

ness of bolts, rivets, and similar connections, and incipient failures of brackets, frames, or other structural parts can be detected in the process of thorough cleaning, which would otherwise pass unnoticed until breakage had occurred. Cleanliness is required not only for the sake of appearance, but also to discover what is underneath the dirt.

Inspections of vehicles at repair shops or other localities where placed for repair will not follow a specified routine, but inspection will be conducted to determine whether the necessity for repair has been due to improper operation, lack of cleanliness and lubrication,



Layout of tools for inspection.

or failure to maintain proper adjustments. This inspection will also disclose whether the necessity for repair has been anticipated by the responsible officer in charge of the operation of the vehicles, and the repair organization advised in advance as to work which will be required by it on specified vehicles in order that said organization may plan its work accordingly, requisitioning spare parts if necessary, or providing for repairs not requiring replacement. The expert technical knowledge and experience of the officer in charge of a repair organization should be utilized in connection with vehicles developing trouble before the failures have occurred in service.

Upon completion of the inspection specified in the foregoing paragraphs, the commanding officer will initiate such procedure as may

be necessary to insure the maintenance of the highest possible percentage of his equipment in serviceable operating condition.

If a technical inspection is made at this time, it should be in conformity to the procedure outlined. Ordinarily, the technical inspection should not be made at the same time as the general inspection on account of the length of time needed to make a detailed technical inspection, and because of the fact that to interpret most intelligently the mechanical condition of a machine, it should be inspected when it is more or less dirty, so as to show up defects brought out in contrast by a slight coat of dust. After the vehicles and equipment are inspected, the camp, quarters, and kitchens should be inspected in conformity with the procedure laid down in various regulations and orders on that subject.

In general the driver is personally responsible for the cleanliness and condition of the following parts of his truck:

1. Engine.
2. Cooling system.
3. Carburetor.
4. Ignition.
5. Generator.
6. Dash instruments.
7. Engine controls.

The assistant driver is personally responsible for the cleanliness and condition of:

1. Clutch.
2. Transmission.
3. Drive shafts.
4. Rear axle.
5. Rear springs.
6. Brake mechanism.
7. Rear wheels.
8. Front axle.
9. Front springs.
10. Front wheels.
11. Hood.
12. Fender.
13. Body.

PERSONAL CARE OF TIRES.

(a) Most tire troubles are the result of abuse rather than use.

(b) Cut off all loose ends and remove any stones or glass imbedded in tires. In case of dual tires remove stones from between the treads.

(c) Start and stop the vehicle gradually.

(d) Do not turn the steering wheel when the truck is stationary.

(e) Keep the tires free from grease and oil, and avoid ruts, running in car tracks, and sharp stones in the road.

(f) Avoid overloading and overspeeding.

(g) Avoid loose lumber or boxes, as they may contain nails or wire that would tear the tires. (NOTE.—Before cutting rubber moisten it and it will cut much more smoothly.)

(h) Do not run over paper bags, or packages, as they may contain glass bottles.

GASOLINE MUST BE HANDLED WITH CARE AND COMMON SENSE.

The following precautions in regard to fire should be heeded:

Gasoline vaporizes easily, and as the vapor is heavier than air it sinks to the ground. When filling the gasoline tank, be sure that there are no open lights or fire near. If the tank is to be filled at night, do not use a flame lamp. Use an electric flash lamp. Do not use the gasoline funnel for anything but gasoline.

IN CASE OF FIRE DO NOT TRY TO PUT IT OUT WITH WATER.

The burning gasoline will float and spread the fire. Always keep a pail or two of sand handy, and smother the flame with it. A fire extinguisher should also be kept at hand.

In case of a truck catching on fire, the first thing to do, if possible, is to turn off the supply cock from the tank to the carburetor, push the car away from the blazing gasoline on the ground, then cover the flame with sand or dirt, if a fire extinguisher is not available.

Do not flood the carburetor and let a pool of gasoline collect under it when priming, as a chance short circuit may give a spark that will set it on fire.

Keep all engine parts, drip pans, and under parts of vehicles clean and the gasoline that drips into these parts will soon evaporate, thereby greatly reducing the possibility of fire.

COLD WEATHER PRECAUTIONS.

Upon the approach of the winter season it becomes the duty of every member of the Motor Transport Corps, and particularly those responsible for the care and upkeep of motor equipment, to see that all necessary precautions are taken to prevent damage incident to the freezing of water in radiators, cylinders, and pumps of the motor transportation in their care. Experience has demonstrated the fact very clearly that cold weather need have no effect on the efficient operation of motor vehicles provided reasonable and necessary precautions are taken to prevent freezing.

Officers and men responsible will be held strictly accountable for any damage due to freezing.

The following instructions are for the information and guidance of all.

When freezing weather is anticipated, the responsible officer will see that the following precautionary measures against freezing are taken:

ANTIFREEZING MIXTURES.

The antifreezing mixture to be issued will be the best obtainable. The strictest economy will be observed, using this mixture only when absolutely necessary, and in the quantities and for the class of cars prescribed.

It will be necessary to limit the use of this fluid, generally speaking, to staff cars. Experience shows that a calcium chloride preparation has a corrosive tendency, and is destructive to rubber hose, packings, and electric insulations upon which it has dripped or splattered.

(a) This corrosion is due to the solution being used without proper dilution or else impure chemicals. When directions are followed, no serious trouble will result. The practice of adding too much of this solution must be guarded against.

(b) In some cases the solution is ineffective because of the constant renewal of water without maintaining a full strength mixture.

(c) In using any antifreezing mixture, it is essential to follow exactly the instructions furnished therewith.

Nonfreezing solution for radiators (denatured alcohol and water).

Freezing point.	Volume.	Gravity.
	Per cent.	
F		
30°	5	99
20	15	98
10°	25	97
0	30	96 $\frac{1}{2}$
-10	35	96
-20	40	95 $\frac{1}{2}$
-30	46	94
-40	55	92
-50	63	91

Gravity tests of the cooling solution should be taken at least three times each week, and the correct proportion maintained at all times. If the proportion of alcohol falls below specifications, the engine will be in danger of freezing. Should the engine boil from any cause while a solution is employed, a rapid loss of alcohol will result and the correct proportion should be immediately obtained to avoid later freezing.

In this question of care and upkeep of motor equipment the personal element enters to a large extent.

AT NIGHT—WHEN RADIATOR CAN BE DRAINED.

(a) The vehicle should be tilted or inclined so that the water will flow toward the drain cocks and not form pockets.

(b) The radiators, pumps, and carburetors of all motor vehicles will be drained by opening the drain cocks at the lowest point in the circulating system.

(c) As a further assurance that no water remains in the system, the engine will be started and run slowly for a few minutes. Shut off the gasoline supply at the tank, thus allowing the engine to "die," when the remaining gasoline in the carburetor and line has been used.

(d) After the engine has stopped, carburetor should be drained, as very often a few drops of water will have collected at the bottom. This procedure will effectually empty every particle of water from the engine and evaporate any remaining moisture around the cylinders, pump, and radiator.

(e) If the radiator is hot, do not replace filler cap tightly. One or two turns will answer, as very often the metal contracts, thus making removal difficult in the morning. When caps are hinged or clamped, do not entirely close them.

AT NIGHT—WHEN RADIATOR CAN NOT BE DRAINED.

(a) Heaters will be used under the hood to prevent the water from freezing. Side lamps may be used, if special heaters are not available.

(b) If antifreezing mixture can not be obtained, motors should be kept warm by running for a few minutes, say every two hours or oftener, according to temperature. Even when antifreezing mixture is available, intermittent running is desirable to insure facility of starting, by keeping water reasonably warm.

IN DAYTIME—VEHICLE STANDING STILL.

Hood should be covered. Burlap bags filled with straw or dry leaves will serve for this purpose when better means are not available.

IN DAYTIME—VEHICLE RUNNING.

In zero weather water will freeze in the radiator even when the engine is running. Steps must therefore be taken to provide suitable aprons of canvas or other material to cover the radiators. If radiator and hood covers can not be obtained in sufficient number, suitable covers will be improvised from material at hand.

RELEASING BRAKES.

Do not leave vehicles over night with the hand brake set. This practice often results in bands freezing to the brake drums. If hand brakes are not set, blocking must be used.

STARTING MOTORS IN COLD WEATHER.

(a) If radiator is frozen, do not attempt to thaw it out by running the engine—use hot water.

(b) A very cold engine is difficult to start because the oil congeals in the cylinder walls and in the bearings. If it can not be turned with moderately strong pressure on the crank, the water pump is probably frozen. Thaw it out by pouring hot water over it before exerting too much force on the crank. If this is not done the coupling will be sheared or the propeller broken loose from the shaft. If the cooling system has been drained and hot water can be obtained for refilling, cranking will be easier. The consequent warming of cylinder walls will assist in the vaporization of the gas and make the engine start quicker. Warming the intake manifold, flooding the carburetor, and pouring a small quantity of gasoline into the cylinders through the priming cocks are all helpful in getting a cold engine started. Take care not to flood the engine with gasoline. The engine runs best and works most efficiently when operating at approximately the same temperature as in summer weather. Part of the draft through the radiator may be cut off by keeping the radiator partially covered, and in very cold weather it may be advisable to remove fan belt also.

(c) A hose attached to the end of the muffler of a running engine will be of advantage in thawing frozen parts or warming cold parts of other cars.

DRIVING ON ICE OR FROZEN ROADS.

(a) If the wheels are "frozen in" deeply, loosen them up with a jack before attempting to start the truck, or severe strain will be thrown upon all of the driving mechanism. Take care not to injure tires.

(b) When necessary to use chains, put a complete set on both wheels. One or two chains will make the truck jerk forward, thus straining the entire driving mechanism.

DRIVING ON MUDDY OR SNOWY ROADS.

(a) On extremely muddy roads, where the mud is several inches deep, it will be necessary to use chains continuously. This precaution will aid traction and tend to prevent skidding. If the ruts in the road are extremely severe, it will be necessary to have chains on the front wheels. Such precaution is necessary only on roads of a "clayey" nature. In the event that the driver has not taken the precautions of applying the chains, and finds himself in a position where he can not get traction, he must not spin the rear wheels, as "spinning" wheels only dig in deeper, besides oftentimes cutting the tire badly by running it against a rock bedded in the ground.

(b) When there is considerable snow on the ground, similar difficulty in traction will be experienced, and chains should always be used under these conditions. If chains are not available, pieces of rope or twisted canvas tied through the spokes will serve the purpose for traction temporarily.

(c) In cases where the driving must be done in snow or sleet storms, or on wet pavements, all drivers are warned against speed; but they are warned further not to allow the truck to lose its momentum, inasmuch as starting under these conditions will prove difficult.

FIELD OPERATIONS.

LECTURE V.

SIGNALS AND ROAD RULES.

In giving signals the instructor should take particular care to see that signals are executed in a uniform manner, and that no deviations are allowed from the methods and movements prescribed.

Convoy Signals.

[TM—Truckmaster, ATM—Assistant Truckmaster, AD—Assistant Driver.]

Signals.	Given by	Whistle signal	Hand or arm signal.
1. Attention.....	TM ATM	Several short blasts.	Arm held vertical, hand moved quickly from side to side.
2. Crank motors.....	TM ATM	2 long blasts.	Circles described in front of body with right arm.
3. Ready to start.....	AD ATM	None.....	Arm extended at an angle of 15 degrees.
4. Forward.....	TM ATM	1 long blast.	Arm lowered in direction of traffic.
5. Speed up.....	TM ATM	None.....	Arm moved up and down quickly from shoulder.
6. Slow down.....	TM ATM AD	None.....	Arm extended at an angle of 15 degrees, hand moved up and down from wrist.
7. H. H.....	TM ATM AD	1 long blast.	Arm extended at an angle of 15 degrees.
8. Stop motors.....	TM ATM	2 shorts—1 long blast.	Arms crossed in front of body and moved sharply to sides.
9. Reverse convoy.....	TM ATM	Seven 1 shorts and 1 long blast.	Arm extended vertically and circles described from the shoulder.
10. Assemble (right or left).....	TM ATM	1 long—1 short and 1 long blast.	Arm extended vertically and circles described with hand from wrist.

ATTENTION.

Whistle signal: Several short blasts.

Arm signal:

Right hand moved from wrist; moved sharply from side to side above the head. This signal is given by the truckmaster and repeated by the assistant truckmasters, who face toward the rear of the column, and stand at "attention" after giving the signal.



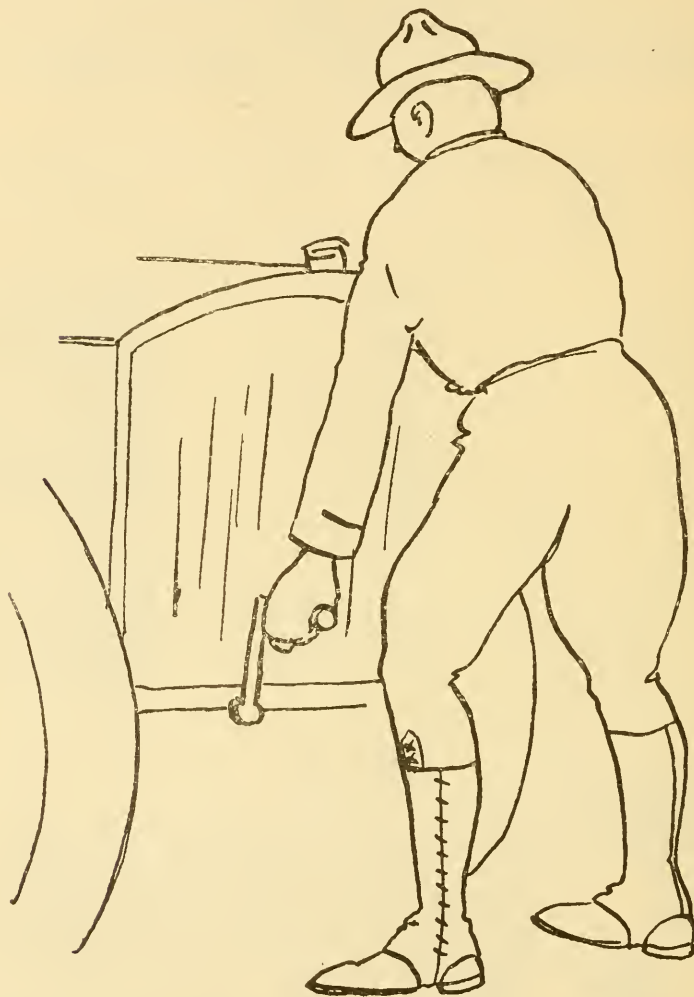
When the signal is given the assistant driver assumes the position of a soldier at "attention" just back of the left front wheel hub, close to the fender and facing to the front.

The truckmaster takes his position 2 yards to the left of the front wheel hub of the leading truck of the first section.

The assistant truckmaster of the first section takes his position 1 yard to the left of the front wheel hub of the second truck of his section.

The assistant truckmasters of sections 2 and 3 take their positions 1 yard to the left of the front wheel hub of the first truck of their respective sections.

The mechanic takes his position 1 yard behind the assistant driver of the repair truck, or file-closer, and stands at "attention," facing to the front of the column.



Crank motor with left hand.

The assistant mechanics take their positions 1 yard behind the assistant drivers of the last trucks in the first and second sections, and stand at "attention," facing to the front of the column.

CRANK MOTORS.

In cranking motors, the instructor should insist that the left hand be used as illustrated in sketch.

Where necessary to use two hands, the operator should place the left hand in front of the right, taking care to step far enough away from the truck to avoid injury, in case of back fire.

Whistle signal: Two long blasts.

Arm Signal: Circles described in front of body with right arm in a clockwise direction, given by the truckmaster, repeated by assistant truckmasters.

Driver turns on switch. Assistant driver steps to front of truck and cranks motor with left hand. When motor starts, the assistant driver stands with one foot on the left running board and the other in the cab, facing toward the front of the column; the driver disengages the clutch and places the gear shift in first speed. Upon completion of this operation, the assistant driver raises his left arm 45 degrees from the vertical as signal to assistant truckmaster that the truck is ready to move.

The chief mechanic and his assistant then take their places on the seats of their respective trucks.

When the assistant truckmaster of the third section observes by the signals that all of the trucks in his section are ready to move he does an about face and passes the "ready" signal to the assistant truckmaster of the second section, who in turn observes if all his trucks are ready and who then does an about face and passes the signals to the assistant truckmaster of the first section, who repeats the movements as described above.

In giving the signals on a winding road, if the truckmaster is unable to see the signal of the assistant truckmaster of the third section, the assistant truckmaster of the second section will raise both arms to the "Ready" position to indicate that both the second and third sections are ready to move.



Crank motors.



Forward.

FORWARD.

Whistle signal: One long blast.

Arm signal: Right arm raised over head and lowered to horizontal position in front of body.

This signal is given by the company commander and repeated by the truckmaster and assistant truckmasters who face toward the front of the column.

Drivers engage clutch and vehicles start. Truckmaster will give signal to start after each assistant truckmaster has given the signal of readiness by raising his left arm as shown in illustration. Should a motor fail to start, the convoy will proceed. This truck will get under way and overtake the convoy as soon as possible.

SPEED UP.

Whistle signal: None.

Arm signal: Carry the hand to the shoulder; rapidly thrust the hand upward the full extent of the arm several times.

This signal is given by the truckmaster and carried on by the assistant truckmasters.

SLOW DOWN.

Whistle signal: None.

Arm signal: Arm extended upward and to the side at angle of 45 degrees. Hand moved up and down from the wrist. Truckmaster gives signal and assistant drivers pass it on.

HALT.

Whistle signal: One long blast.

Arm signal: Arm extended upward and to the side at 45 degrees angle, and held stationary. Truckmaster gives signal and assistant drivers pass it on. Assistant truckmasters stand on ground, facing toward the front of column, in preparation for next signal.



Speed up.



Slow down.



Halt convoy.

In using either the stop or slow-down signal the assistant driver must make certain that the signal is properly understood by the truck following him, as for example:

(a) When driving at night and stop signal has been given, the assistant driver will, if necessary, get off the truck and inform the driver of the truck following by verbal signals that the convoy is halting.

(b) In the case of narrow seat on a wide-bodied truck, the assistant driver will get down on the step of his truck and face the truck behind if necessary, to make his signals understood.

STOP MOTORS.

Whistle signal: Two short and one long blast.

Arm signal: Arms crossed in front of body at waist and moved sharply from side to side. Truckmaster gives signal and assistant truckmasters pass it on to their respective sections.

REVERSE CONVOY.

Whistle signal: Several short and one long blast.

Arm signal: Truckmaster describes large circles above head with right arm. Drivers stop vehicles, throw in reverse, and back trucks to the left of the road.

First speed is then engaged and while slowly moving the wheels are cramped to the right. The trucks move around and forward to the right side of the road, taking up the prescribed distances. Narrow roads may necessitate considerable maneuvering to reverse the convoy.

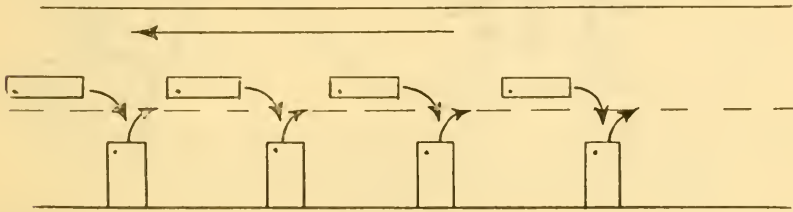


Stop motors.



Reverse convoy.

At completion of this movement the convoy will be in a reversed position: service trucks will pull to the side of the road, permitting cargo trucks to pass, then take their position in rear of column. Convoy will proceed without further orders in new direction.



Method of reversing direction of travel and at the same time keeping road on right.

BACK UP—FORWARD.

Whistle signal: None.

Arm signal: Forearms raised vertically; hands in front of and opposite shoulders; arms moved forward and backward horizontally in direction truck is moving. Palms held toward truck is signal to back; backs of hands toward truck indicate the signal for forward movement.



Back up.



Forward.

If the man signaling backing directions desires truck moved to his right, he so indicates by holding left hand on chest and moving right arm sharply to the right, repeating the movement until truck has covered the necessary ground. For a backing movement to the left, the corresponding signal is given by holding right hand on chest, and moving left arm to the left.

If, during the backing process, it is desired that wheels be cramped to right or left, signals are given with short, quick motions of the

right or left arm, according to direction desired. The speed of the arm movement always indicates the rapidity with which the truck movement is to be executed.

When it is necessary to back the truck, the assistant driver takes position in front of truck to give the necessary signals to his driver. Careless backing of a vehicle may send it into a ditch. The driver should not look around while backing, but should act only on signal from assistant driver. Verbal signals may be used to augment hand signals, especially at night.

STOP SIGNAL.

In order to stop the truck while backing and turning, the assistant driver so signals by thrusting arms to the side and then drops them down smartly.



Stop signal use when backing trucks.



Assemble.

ASSEMBLE.

Whistle signal: One long, one short, and one long blast.

Arm signal: Truckmaster takes his position at head of column of trucks, on flank where assembly is to be made, and describes small circles above head with right hand from wrist.

When this signal is given the assistant truckmasters assemble the drivers and assistant drivers of each section in column of two's at head of their sections. Assistant truckmasters of the last two sections then assemble their drivers and assistants on the first section, and report to the truckmaster, who then assumes command of the three sections. Men are arranged in column of two's, in order of trucks, drivers on the right, and assistant drivers on the left.

The assembly is for purposes of instruction or inspection; therefore, when the column has assembled, it will be faced to the right to bring it in company front.

When the assembly has accomplished its purpose, and it is the desire of the commander that the men return to their trucks, the truckmaster being so instructed, will command, "Sections Post!" Each assistant truckmaster will face his section into column formation, and march it forward until the driver and assistant driver of the first truck are opposite the front hub of their truck. The assistant truckmaster halts the section, and commands, "Drivers Post!" The

driver and assistant driver of the first truck take their positions on the driving seat, while the remaining drivers and assistants are marched to their respective trucks, halted, and posted.

The command, "Fall out," which permits drivers and assistants and others of the convoy to leave their posts, is a verbal signal passed down the line of trucks. "Fall in" is not used on convoy, the signal "Attention" being employed to bring men to their posts.

ROAD RULES.

1. Drivers will keep trucks on the right-hand side of the road at all times, whether standing or moving.

2. In passing vehicles traveling in the same direction, the driver will pass on the left, and sound his horn.

3. A driver will always pass an approaching vehicle on the right and give it half the road.

4. Never block a road.

5. In passing a standing or moving convoy, a driver will slow down and sound his horn.

6. When convoy is halted, all men must be kept off the road.

7. The convoy must be kept together.

8. Assistant driver must at all times keep driver in touch with truck immediately behind, in order that speed may be uniform.

9. A driver will never abandon his vehicle except on order of his commanding officer.

10. Drivers will not permit unauthorized persons to ride on vehicles.

11. If any repairs are needed driver will report same immediately.

12. The military police on duty will be strictly obeyed.

13. The use of the muffler cut-out is absolutely forbidden at all times.

14. When vehicles are halted, motors will not be left running to exceed one minute under any circumstances.

15. Appropriate signals will be given when changing direction or stopping.

16. Examine amount of oil, gasoline, and water after each stop.

17. Investigate and find the cause of all unusual noises.

18. Do not smoke while driving.

19. Engine is to be used as a brake when descending hills, by shifting to lower gear.

20. When vehicle is stopped on a hill, put a block or stone under the rear wheel.

21. Road signs and signals will be given strict attention.

22. Motor vehicles will not be driven by anyone except regular drivers or assistant drivers assigned thereto, unless in case of emergency.

23. Never use exposed flame or oil lantern in filling gasoline tank or working on carburetor. Use electric torch.

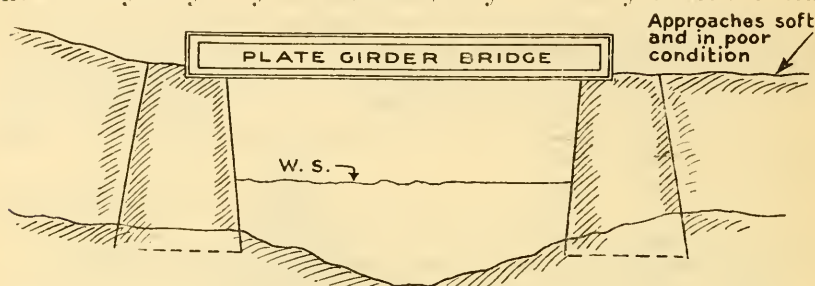
24. When driving in cities, towns, or villages, never double a vehicle moving in the same direction.

25. A slower moving convoy must never be doubled unless commander of overtaking convoy makes certain that doubling can be completed without confusion.

26. Never double a halted convoy, a halted body of troops, or body of troops passing in the same direction without first gaining consent of the officer in charge.

27. The speed of the convoy is governed by the last truck, the distance is taken from the truck ahead.

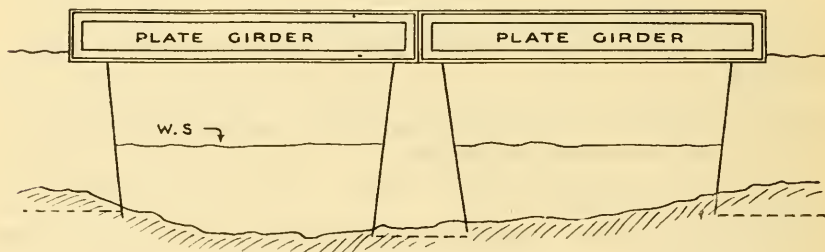
28. In proceeding along unknown roads, bridges should be examined before the convoy is allowed to pass. In general the rule is to slow down to 6 miles per hour, and to allow only one truck at a time upon one span of the bridge. In case of pontoon bridges, no matter how firmly they may be anchored, they invariably stretch in semi-



Only one truck on bridge at a time.

circular form on the downstream side, in that way spreading apart the flooring timbers. In passing over these bridges with a convoy, it is advisable to have the trucks keep to the upstream side to avoid accidents.

The convoy commander should first secure the location of bridges from his map and on approaching one, order his trucks to spread out. This will eliminate the confusion which generally follows when a line of trucks comes to a bridge suddenly and has to slow down. If



Only one truck on each span at a time.

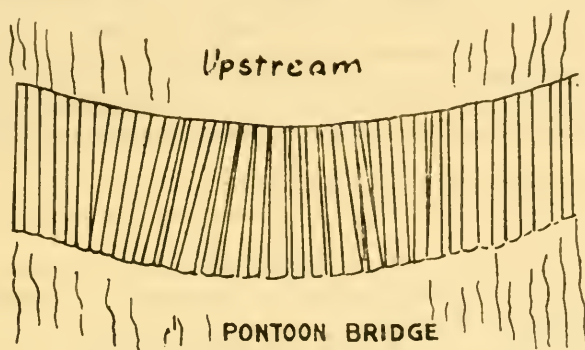
this precaution is taken, the convoy will pass the bridge without jamming and confusion. The first truck, after it has crossed the bridge, slows down to allow the other trucks to close up.

29. If a truck is forced to leave the convoy for repairs, the driver should promptly pull off to the extreme right hand side of the road. In case a truck is unable to move under its own power it should be towed or pushed to a position well off the road by one of the other trucks. The driver will then notify the company mechanic that he requires assistance. The road repairs should not be allowed to delay the mechanic for more than 20 minutes. If further work is neces-

sary on the truck, it will either be towed in, or the mechanic will leave men to work on the truck, with orders to rejoin the convoy at the earliest possible moment. A truck, after overtaking the halted convoy, will upon securing permission from the officer in charge, drop in behind the last truck in the section to which it belongs. When the convoy proceeds again the truck will take its proper place in the section. Officers will not permit their trucks to run over soft ground if it can be avoided, and will instruct their drivers to keep two traction wheels on the hard road at all times.

30. Each truck shall carry at all times a 50-foot tow rope or chain.

31. In case of a long convoy in which it is necessary to take a gasoline truck, this truck should be placed immediately in front of the light repair truck.



Keep to upstream side and use extreme care.

GENERAL RULES.

1. No vehicle will be left by the road side unattended. In case of a breakdown or other cause for delay, the driver will remain with his charge until the vehicle has been returned to its base or after relief by competent authority, e. g., commanding officer.

2. There is no excuse for a broken-down vehicle being left in the middle of the road.

3. A guard will be placed over vehicles parked for the night.

4. Motor vehicles will be driven without lights only at such times and such places as specified by the traffic control or road signs.

5. Drivers should employ their spare time, when trucks are being loaded and unloaded, in oiling, greasing, and cleaning their trucks.

6. Guards to regulate traffic and give warning of danger, must be posted well in advance of the convoy, i. e., at railroad grade crossings, at the intersection of main streets or roads, etc.

TRAFFIC REGULATIONS.

1. Drivers will keep on the right hand side of the road at all times whether moving or standing.

2. In changing direction or stopping, always give appropriate hand signals.

3. Pay careful attention to road signs and to convoy signals.

4. Never proceed on a road in a direction opposite to that prescribed for traffic circulation.

5. Always give way promptly to faster moving vehicles, upon signal.

6. On dry dusty roads it is necessary to reduce the speed, in order to keep down the dust. Clouds of dust attract the enemy's attention. Reducing speed also reduces liability to accident, especially at night.

7. Loaded trucks have the right of way over empty convoys.

8. Drive slowly at night when traveling without lights. This avoids accidents and trucks are less apt to be lost.

9. If driving with lights and a car or convoy approaches, dim your lights. It avoids accidents due to blinding headlights. This is especially true when the approaching car or convoy is driving without lights. In approaching or passing vehicles under such conditions dim your lights at once. Not only does the light blind the men, but the shadows cast are very confusing to a man when driving in the dark.

10. Dim all lights in towns and cities.

11. In descending a steep hill use the engine as a brake by shifting to a lower gear.

12. Do not make unnecessary noise with horns or klaxons.

13. Observe the following rules for "doubling," i. e., passing traffic moving in the same direction.

(a) In passing a standing or moving convoy, a driver will slow down and sound his horn, when necessary for safety.

(b) A vehicle must never double moving vehicles having similar or higher speed limits. Thus a tractor must not double a truck, and a truck must not double a touring car, etc., unless such action is agreed to by the driver of faster moving vehicle.

(c) A vehicle must never double when going around corners or sharp curves.

(d) Vehicles must never attempt to double when there is a block in the traffic ahead.

(e) Never double in towns or villages.

(f) Never double while descending steep hills.

(g) Never double just before reaching the top of a hill.

(h) Do not double unless the road is wide enough to allow 18 inches or more between vehicles.

(i) In doubling, do not make sharp angles before or after passing the vehicle in front.

14. In meeting vehicles coming in opposite direction observe the following rules:

(a) A driver will always pass an approaching vehicle to the right and give it half of the road.

(b) Slow down, if the approaching vehicle is throwing clouds of dust across the road.

(c) Slow down to half speed, if the road is narrow or rough.

(d) In case of traffic blockade or other obstacle at the point where two vehicles will meet, the vehicle having the clear road ahead has the right of way, and the other vehicle must slow or stop if necessary.

15. *At crossroads* observe the following rules:

(a) Unless the crossroads can be seen in either direction for 75 yards, slow down.

(b) A vehicle traveling on a main road has the right of way over vehicles traveling smaller intersecting roads, unless specific instructions to the contrary are prescribed by the traffic police.

16. *In crossing railroads:*

(a) Slow down.

(b) If gates are closed, do not start before they are open.

(c) In case the road passes under the railroad, make sure that there is adequate clearance between the bridge and the top of the vehicle.

17. *In halting*, observe the following rules:

(a) Vehicles will not halt on bridges, in narrow roads, or defiles, or on turns. They will never halt within 50 yards of a crossroad or road fork.

(NOTE.—Extreme necessity may make this rule inoperative.)

(b) Should a vehicle be unable to proceed under its own power, request should be made on the next one in the rear to pull forward and give assistance.

(c) Drivers when dismounted will keep off the center and left-hand side of the road.

FILE CLOSERS.

The last cargo truck of the convoy should carry the tools, ropes, jacks, etc., which are necessary to effect simple road repairs. This vehicle will be in charge of the mechanic or other experienced man, who will act as file closer, and will have the assistant mechanics as near him as possible, on other trucks available to act under his orders. His duties are to assist any disabled vehicle, and to make proper disposition of broken down vehicles, subject to the orders of the commanding officer. The file closer will not leave any vehicle of the convoy without taking the proper measures either to repair the vehicle on the road, tow it along with the convoy, or make other proper disposition subject to the decision of the convoy commander. This repair truck should not ordinarily stop more than 20 minutes before going ahead to rejoin the convoy. The regular light repair truck of the company, if taken along, will be placed in the convoy according to the judgment of the convoy commander and will be at his disposition and in charge of a mechanic. The rear of the convoy is usually the best place for it.

ACCIDENTS.

In case of an accident, however trivial, which results in injury to persons or property, drivers will fill in the information called for on Motor Transportation Corps Form 124, a supply of which will be kept on all motor vehicles. Commanding officers will, in every case, institute court-martial proceedings against drivers who fail to render this report immediately upon return to their organization. Immediately upon being informed by means of Motor Transportation Corps Form 124, or by other means that an accident has occurred to one of his vehicles, the company commander will himself make an investigation.

FIELD OPERATIONS.

LECTURE VI.

MAP READING.

A military map is a drawing or plot on which roads, woods, streams, hills, marshes, and other objects of military importance are shown in their relative positions by means of conventional signs.

Military maps differ from ordinary maps in many ways. They give the relative distances, elevations, depressions and directions of all objects of military importance. While an ordinary map might merely indicate a road, a military map would show whether the road is fenced or not, as well as its width, construction, and condition.

The civil map shows only the large rivers, national highways, etc., while the military map shows the width and depth of rivers. Civil maps are used at times as they can be used as a basis for the construction of military topographical maps. Civil maps when available should be carried on long convoys.

Military map reading requires a great deal of time, study, and practice. Before a military map can be of use to a man on a convoy he must be able to look at it and visualize the actual country represented. He must at first figure the distance to be traveled, then be able to see every hill, turn, etc. He must also be able to locate woods, etc. For instance, if he knew that within a certain distance he would be under shell fire, he must be able to look at the map and determine quickly just where shelter may be found, the distance to it, and the time it will take to get there. Practice is most important in acquiring ability to read maps.

The most essential points in map reading are:

First. To be familiar with the various signs and symbols used in designating the different objects.

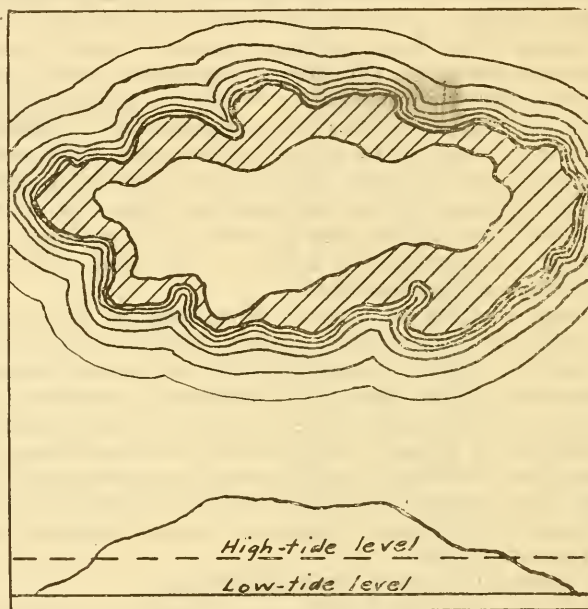
Second. To understand that each distance on the map is a fixed part of the corresponding distance on the ground. For example, if two places are an inch apart on the map and a mile apart on the ground, an inch measured anywhere else on the map would also be a mile.

Third. To realize that the directions of objects on the map correspond to their actual directions from each other on the ground.

Fourth. To remember that contours and hachures must convey a clear mental picture of the ground actually represented. Two methods of showing the formations of the ground are: First, by means of contours; second, by means of hachures. Of the two, the first method is more generally used by the Army; they require more time to make but are more accurate. The use of hachures is confined to field sketches, where the question of time is paramount and where only approximation is necessary.

Contours are the lines cut on the surface of the earth by imaginary horizontal planes at equal vertical intervals from each other. They are numbered from 0 up, the sea level being assumed as zero. For example:

In the sketch is shown a rock which is surrounded by the sea at a lower or higher level, depending upon the rise and fall of the tide. If at high tide you mark the water level and continue to mark the changing level at stated intervals, such as every two hours, you would have a series of lines and each line would represent the surface of the water for that period, and these lines represent contour lines for that particular rock. This principle extended to cover the entire section of country being mapped will give contour lines for that section.



Shaded area shows surface covered at high tide.

(a) A watershed along which the water divides, flowing away from it on either side, is indicated by the higher contours bulging out toward the lower, as is shown in the sketch between the points E and F.

(b) A water course, or valley, along which rain falling on both sides of it joins in one stream is indicated by the lower contours bending out sharply toward the higher ones. There are several examples of these valleys shown on the specimen contour map.

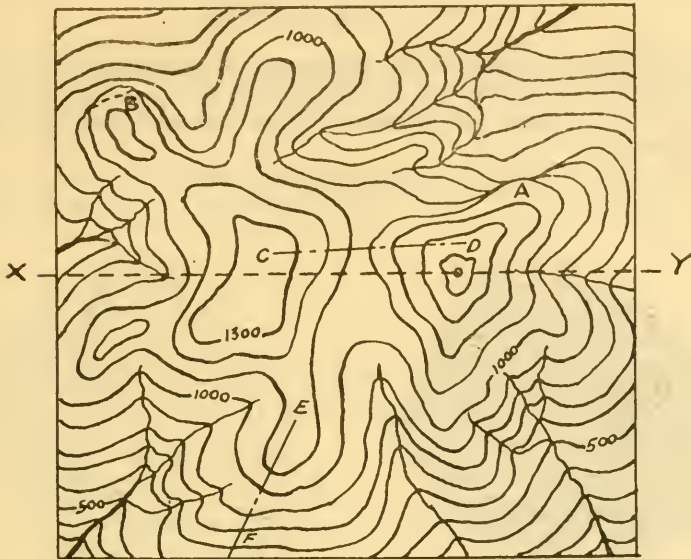
(c) Contours of different elevations which unite and become a single contour represent a vertical cliff, as shown at A.

(d) Two contours of different elevations which cross each other represent an overhanging cliff, as shown at B.

(e) A closed contour represents either a hilltop, or a knoll, or a depression, a hilltop is shown when the smallest closed contour is

higher than the adjacent contour, and a depression when the smallest closed contour is lower than the contour next to it. C and D are both knolls.

(f) A saddle, or column, is shown by two contours of greater elevation on two sides of it, and two of lower elevations on the other



A—Perpendicular cliff. B—Overhanging cliff. C—Plateau. D—Knoll. C to D—Saddle-back pass. E to F—Watershed.

two sides, as illustrated between the points C and D on the sample map.

If the student will first examine the drainage system, as shown by the courses of the streams on the map, he can readily locate all of the valleys. Knowing the valleys, the hills and ridges can then



Section through X—Y.

easily be placed, even without reference to the numbers on the contours.

A second method of representing elevations on the ground on a map is by means of short lines called hachures. Where no hachures are found on a hachured map, the ground is either a hilltop or a flat lowland, and the slopes are roughly indicated by the varying blackness and nearness of the hachures. The darker the section the steeper the slope, and the lines always run in the direction of the

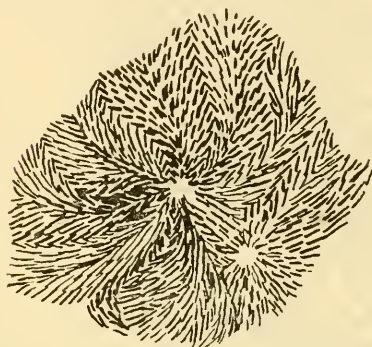
steepest slopes of the ground. The lines of the hachure always radiate from the inside of the contour covering the area in question.

(NOTE.—An excellent discussion of the use of contour lines will be found on the back of maps issued by the Geological Survey.)

ACCIDENTS OF THE SURFACE.

This includes all elevations or depressions upon the surface of the ground, whether natural or artificial, which might be an aid or hindrance to military operations. These are indicated by certain conventional signs.

On one of the following pages will be found the symbols in general use by the Army. They should be studied in order to get the



Hachure lines.



Contour lines.

full benefit of the map. All information which is needed on a military map may be grouped under the following heads:

1. Direction.
2. Distance.
3. Contour, or shape, of the ground.
4. Accidents of the surface.

Direction is indicated on the map by the established symbols. The general rule of map reading and map making is that the top of the map is always north, unless otherwise indicated. The map maker ordinarily places on his map an arrow or a needle, the head of which points toward the north. N., or north, as usually indicated, means the true north as distinguished from the magnetic north. When the compass is used, its needle points not to the true north but to the magnetic north. The variation of the magnetic needle from the true north is frequently indicated by a second arrow, or the true north line is expressed in degrees, or fractions, minutes and seconds, of degrees.

For map reading purposes, the difference between the two directions, as well as the reason for it and the method of its determination, may be disregarded. Or, if the compass is used, the magnetic north may be taken and the true north disregarded.

ORIENTATION OF A MAP.

As ordinarily used, orientation means the placing of a map so that directions on the map are parallel to the corresponding directions on the ground.

DISTANCE.

Distance is expressed on the map by its scale; that is, the scale of the map is the expression of the relation between distance on the ground and the corresponding distance on the map.

METHODS OF REPRESENTING SCALES.

There are three ways in which the scale of the map may be represented:

First: By an expression in words and figures, as: 1 inch equals 1 mile.

Second: By what is called the natural scale, or the representative fraction (R. F.), which is the fraction whose numerator represents units of distance on the map and whose denominator represents units of horizontal distance on the ground, being written thus:

$R. F. = \frac{1}{63,360}$, or 1:63,360; or 1 is 63,360; all of which are equivalent expressions and are to be understood thus: That the numerator is the distance on the map and the denominator is the horizontal distance on the ground.

Third. By what is called the graphical scale. This scale is a line drawn on the map, divided into equal parts, each division being marked, not with its actual length, but with the distance it represents on the ground.

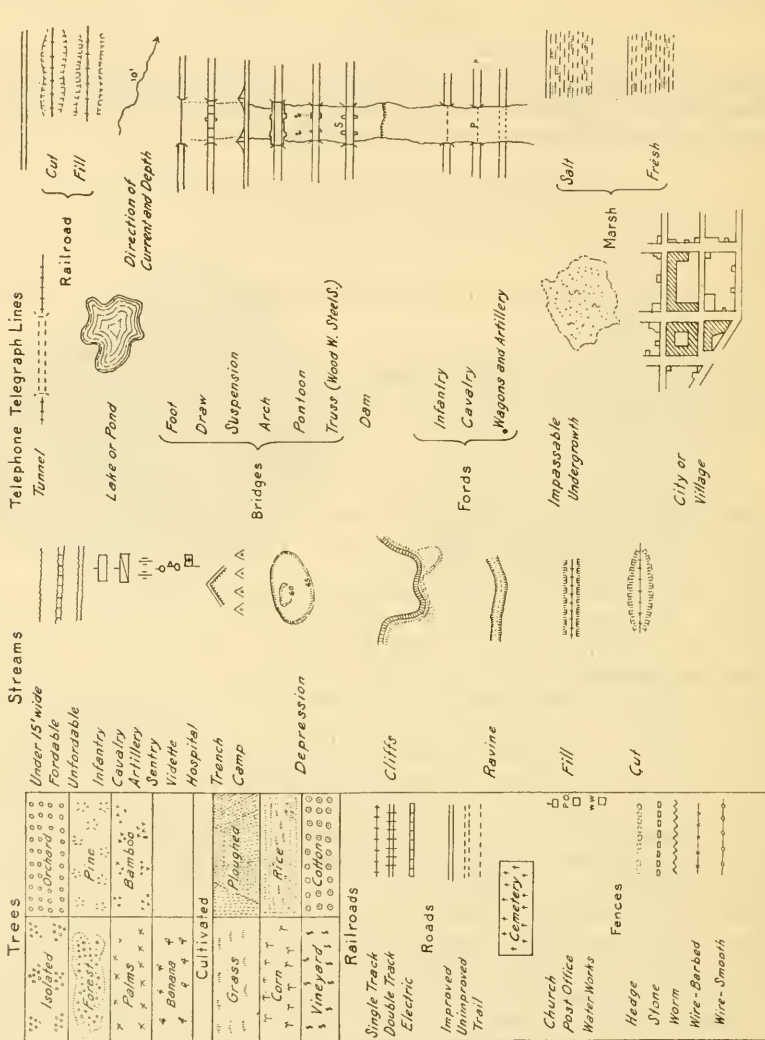
It can readily be seen that a map's scale must be known in order to have a correct idea of the distance between objects represented on the map. This is essential in determining length of march, ranges of small arms and artillery, relative lengths of marches by different roads, etc. Therefore, if under service conditions, you should have a map without a scale, or one expressed in unfamiliar units, you would first of all be compelled to construct a scale to read yards, miles, or some other familiar unit.

With the increasing number of national highways being constructed it will be of advantage for a Motor Transport officer to acquaint himself with the various markings used to designate these roads and to get a general idea of the direction and routes they take.

Training map No. 1 designates the routes of the present national highways and their markings. A few of the more prominent ones, such as the Lincoln Highway, The Dixie Highway, the Yellowstone Trail, and Jefferson Highway, are marked throughout their entire lengths. The remainder more or less so.

One of the methods proposed and used to a very small extent to log roads—that is, to show upon the map all necessary information as to kinds of roads, width, etc., is shown in the training map No. II, with the bridge sheet and key. This illustrates what may be done in this direction and might be used locally in charting roads. The

numbers surrounded by circles refer to the bridge sheet; each bridge is marked to show the kind of material used, width of roadway, and amount of safe load. The roads are described as to width, construction, and their passability at different seasons of the year.



Typical conventional signs.

PRACTICAL MAP READING.

Let us take the training map No. III, published separately, and systematically read it.

Q. What is the scale of the map?—A. It is 3 inches equal to 1 mile; that is, 3 inches measured in any direction on the map are equal to 1 mile on the ground. Any $1\frac{1}{2}$ inches on the map will represent one-half of a mile on the ground. We see that there is a representative

fraction on the map. This is only another method of indicating the scale.

Q. How has it been determined?—A. Remembering that a representative fraction is one reduced to unity in which the numerator represents the map distance and the denominator the ground distance we have:

$$\frac{\text{Map distance}}{\text{Ground distance}} = \frac{3 \text{ inches}}{1 \text{ mile}} = \frac{3 \text{ inches}}{63,360 \text{ inches}} = \frac{1}{21,120}$$

This may also be expressed 1:21,120; that is, one unit of measure on the map represents 21,120 of the same units of measure on the ground.

You observe that this map has no meridian on it. How are you to determine directions? When a map has no meridian line it is safe to assume that the reading matter runs from west to east and that the up and down edges of the map run north and south. A line through Fairview Schoolhouse and Goodintent Schoolhouse runs north and south. This line would serve as a meridian for work in the center of the map and the borders for meridian lines along the edges of the map. You observe a little V-shaped marking at the bottom of the map. The line to the right shows the true north, and the one to the left shows the magnetic north; that is, the former, if the map were oriented on the ground, points directly to the north pole and the latter to the magnetic north. There are comparatively few places on the earth's surface where these lines coincide. In this case the magnetic declination is 7 degrees; that is, if you were to take a bearing with a compass there would be a variation of 7 degrees from the true north.

Q. What is the direction of Hunterstown from Fairview Schoolhouse?—A. North 52 degrees east. This is determined as follows: Draw a line connecting Fairview Schoolhouse with the crossroads at Hunterstown. Draw another line connecting Fairview Schoolhouse and Goodintent Schoolhouse. This latter is your meridian line. Lay a protractor with its 0–180 degree edge along the meridian with the center at Fairview Schoolhouse. Read along the edge of the protractor to the point where the line connecting Fairview Schoolhouse and Hunterstown emerges from under the protractor. This is the reading of the direction.

Q. What is the direction of Granite Hill Station from Goodintent Schoolhouse?—A. South 41 degrees east. Use the same meridian line and pursue the same method as before indicated.

Note the scale of map distances of contour intervals. Take the space to the left of the scale marked 1 degree. This means that any place on the map where the contours are spaced these distances apart indicate that the ground at that point slopes just 1 degree. Where the ground is steeper the contours are spaced closer together. By keeping this scale in your mind you can tell by observation the approximate slope of the ground at any point on the map. The ability to understand contours so as to determine the slope or grade of a road is of considerable importance in motor transport work.

Note the statement below the scale, V.I.:20 feet. This means that the vertical distance between contours is 20 feet. So you know immediately that between every two contours, no matter what their distance apart may be, there is a vertical difference of 20 feet.

Q. Suppose the map had no such statement on it? How would you determine this contour or vertical interval?—A. By an inspection of the map. You will observe that the contours from the ridge just south of Goldenville are numbered. These numbers indicate that the vertical intervals between contours is 20 feet.

Q. What is the elevation of the Grubey House?—A. We see that this house lies about midway between the 580 and 600 contours; the elevation is, therefore, about 590 feet.

Q. What is the difference in elevation between the McElheny house and the Hamilton house?—A. We see that the former has an elevation of 540 feet and that the 640 contour passes through the latter. The difference between these is 100 feet, so that the Hamilton house is 100 feet higher than the McElheny house.

Q. Where is the highest point on the map?—A. The 707-foot hill west of Goldenville.

Q. Where is the lowest point on the map?—A. The lowest point on any map will be found at the point where the largest body of running water leaves the map. This will be found in the northwest sector about 1,400 yards southeast of the Boyd schoolhouse.

In order to facilitate the further reading of this map take a package of "crayolas" and proceed as follows:

1. With the blue crayola line out all the stream lines. This will show at a glance all the water system of the country covered by the map.

2. With the red crayola line out the 560-foot contour. This will show you the outline of the western watershed running along Oak Ridge and its extension to the north, the watershed immediately west of the main watercourse, and that to the east in the vicinity of Hunterstown.

3. With your green crayola line the 500-foot contour. Make note of its crooks and turns which indicate the shape of the ground throughout its course, then compare the green line with the red line indicating the 560 contour. You ought from this process to have a very good idea of the country covered by the map.

Tracing out the water system of the country included in the map we find that the main watercourse runs from northeast to southwest practically parallel to the 549-583-501-543-531 road. Numerous branches lead off to the east and west, the main one to the east crossing the above-mentioned road near 501, where it separates into two branches, one heading in the high ground in the southeast sector of the map and the other in the high ground just west of Hunterstown. The main branch to the west leaves the stream about 1,200 yards due west of 543, runs in a northwesterly direction to a point 700 yards southwest of the Varney place, and then turns northeast and runs parallel to the main stream to the Hermon place and forming the watershed lying between the two streams. Another small stream leaves the main stream and heads near the Boyd schoolhouse. Another heads near the C. Topper place and runs a little west of south, forming with the main stream and its tributaries the water-

shed designated as Oak Ridge. Another small stream heads in the vicinity of Goldenville and runs southwest. This and the branches of the main stream form the watershed which lies to the north in prolongation of Oak Ridge. Over in the northeast sector of the map there is an independent system of watercourses that head to the south of and in the vicinity of Hunterstown, and these with the branches from the main stream form the watershed west of Hunterstown.

With your colored map you will be able to pick up all these points. The study should leave you with a good mental picture of the country covered by the map. You should be able to approximate distances and to measure the distance from one point to another with accuracy. You should have a good idea of the vegetation covering the country and how it would look from any point on the map. You should have knowledge of the shape of the ground, the steepness of slopes, etc.

FIELD OPERATIONS.

LECTURE VII.

LOADING.

TROOP LOADING.

(See diagram.)

The transportation of troops presents a number of features not to be found in ordinary cargo transport, and company commanders must at all times be in a position to prepare their trucks for this purpose at short notice. All portions of the truck equipment that have been removed, such as covers, benches and bows must be kept together where they can not be molested or lost, and can be readily replaced on the trucks. The company commander will ascertain that the oil, gasoline, and kerosene supply of each truck is adequate, and that the condition of the lamps is good. He will ascertain the probable duration of the convoy and provide his men with food and clothing accordingly. It must be remembered that the troop capacity for a given truck includes the personal equipment of the troops, so that, unless called for, extra baggage trucks need not be provided. One cargo truck in each company will be left unloaded so that in case a truck becomes disabled the troops will not be delayed. The trucks will be equipped with seats 18 inches wide and extending the full length of the truck on both sides. For number of men that can be carried in trucks of various sizes, see loading table "Miscellaneous" at end of this lecture.

HANDLING OF GROUP CONVOY.

An officer is designated as commanding officer of the convoy. He has complete charge of all units of which it is composed. He is responsible for all necessary arrangements; the issuing of the required orders, proper routing, and the discipline of its personnel. He selects the assembly point where all the units meet to join the convoy, and the times when they shall arrive at this point. He chooses the resting and stopping places to be made by the convoy when en route.

In order to get the trucks together an assembly point is chosen, for example: There are 10 trains which are to operate as a group. They are stationed at different points, and must be brought together. A point is chosen near the area in which they are found; in most

cases, a crossroad on the main road which the trucks are to follow. A time is set when each train shall arrive at this point (the first train at 5.30, second at 5.33, third at 5.36, etc., each train following behind the other at three-minute intervals). The officer in charge of the first train acts as a guide of the entire convoy. It is his duty to lead the convoy along the route chosen by the commanding officer, to keep and regulate the speed of the convoy, and in the absence of the commanding officer of convoy to take command. The officer in charge of the last train acts as a file closer for the entire convoy. He is in charge of the repair outfit, and it is his duty to see that all disabled cars are kept going, and to perform all the duties that are required of the file closer. He will keep the commanding officer informed at all times as to the location of delayed trucks, etc. The officers of the companies act in the same capacity as the noncommissioned officers of sections. They follow their companies, and in general, place themselves in the rear of their companies. The train commanders travel at the head of their trains.

Loading of troops must be carried out in a systematic manner conforming to the following specific directions:

All necessary arrangements for loading men must be made well in advance of the arrival of the motor convoy. The convoy commander must be at the loading point well in advance of the departure to complete such arrangements as are necessary, and to reconnoiter the loading ground. If he can not be present he must assign his second in command to these duties.

When the convoy reaches the place of loading it should be halted and faced in the direction that the troops are to be moved. If loading is to be done near a town or city it should be carried out on that side which is nearest the destination of the troops.

When the convoy has halted as prescribed and the necessary arrangements have been made with the troop commander, each driver will attend to dropping the tailboard of his truck and the arrangement of the benches for the men. In the meantime, the noncommissioned officers in charge of each section will assemble the assistant drivers of his section in column, single file, facing the troops, with the men arranged in order of trucks, first truck first, then second, etc. The assistant drivers of the first section are then marched toward the troops, the men of the other sections falling in behind. All the assistant drivers are halted in file, just in front of the head of the column of troops, and then execute "left face," facing center of the road. Then the troops are successively marched off in blocks of 20 (or whatever may be the capacity of the truck), beginning with the first truck, and each assistant driver takes charge of his section of troops, marching at the head until his truck is reached, when he and the driver of his truck attend to the loading of the men and the replacement of the tailboard. The noncommissioned officers of the troops should be in the ranks in order to facilitate counting.

Noncommissioned officers in charge of sections signal to the company commander (or truckmaster) when their sections are loaded. The convoy is ready to start only when all the sections are ready. The officers of the troops are transported in the staff cars (passenger cars) of the convoy, as far as possible, otherwise they are assigned to trucks.

Unload the men, transported in the trucks, with the convoy headed

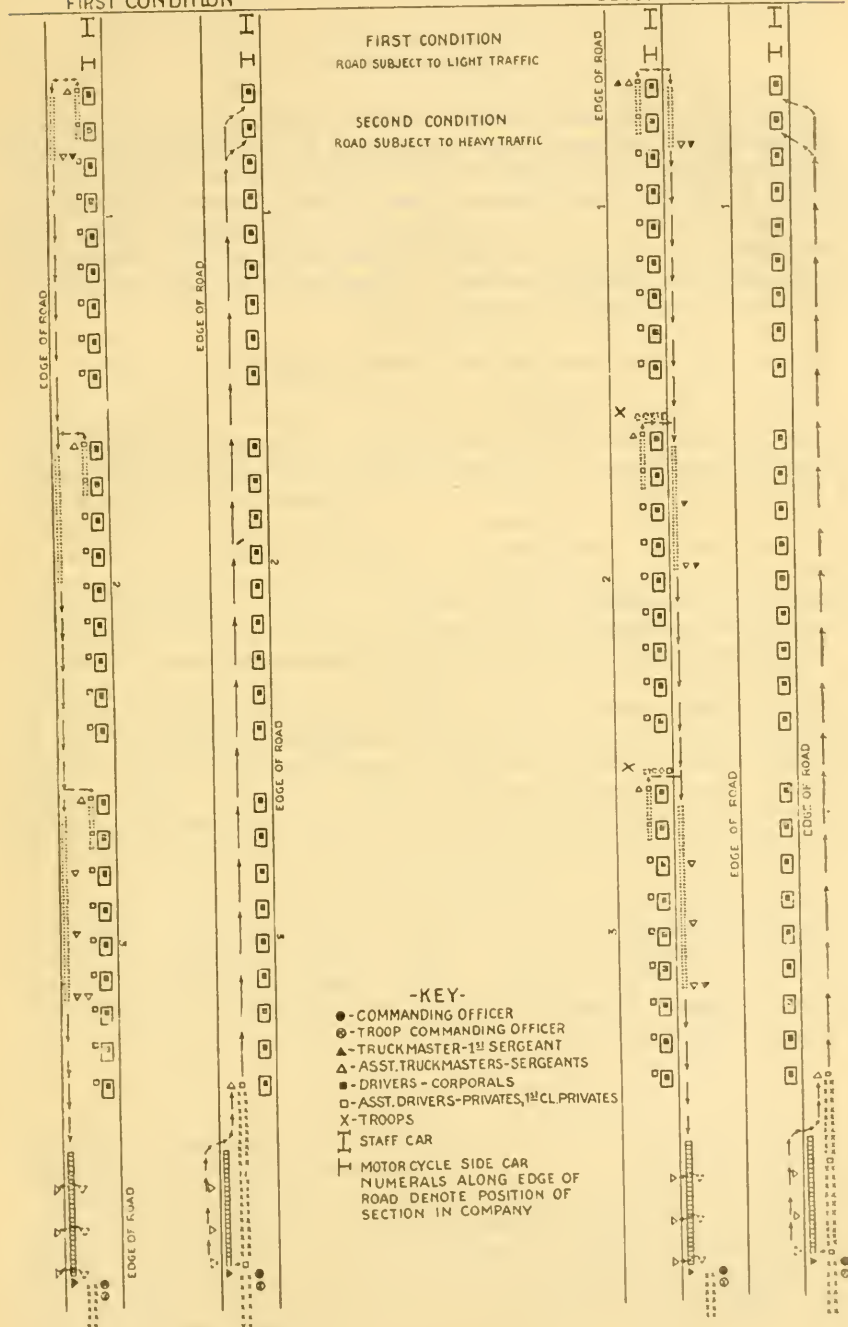
COMPANY FORMATIONS FOR TROOP LOADING

FIRST CONDITION

SECOND CONDITION

FIRST CONDITION
ROAD SUBJECT TO LIGHT TRAFFIC

SECOND CONDITION
ROAD SUBJECT TO HEAVY TRAFFIC



in such direction that the trucks will not have to double back and mix up with the troops getting away.

CARGO LOADING.

(See tables.)

Because of the special problems arising under war time conditions, definite methods of handling cargoes have been devised and must be strictly adhered to in order to obtain good results. There is practically no limit to the classes of goods that the truck is obliged to haul in active service. The requirement of the moment is the chief consideration. Every item that goes into the load of a vehicle used in war service is urgently needed. The necessity for correct handling of cargoes can therefore be appreciated.

GENERAL LOADING CONSIDERATIONS.

To load a vehicle inefficiently not only reduces its carrying capacity but endangers the safety of the entire cargo should the truck be subject to rough travel. A poorly loaded truck with a swaying cargo is always in danger of overturning. Furthermore, one loose box or crate can release an entire load. A correctly loaded truck has greater carrying capacity. Its chances to reach its destination safely are far greater than those of the poorly loaded vehicle. Overloading or underloading are equally undesirable, and are to be guarded against. For correct loading the following principles should be observed:

Heavy goods should be placed at the bottom and near the rear of the truck body, and as nearly as possible over the rear axle in order to give added traction. In building up a load, goods should be equally distributed on both sides, as unbalanced loads will result in swaying and, on rough roads, in broken springs. Hooks should never be used in handling sacked goods. They must be firmly placed. If they shift back and forth, friction will wear holes in the sacks and loss of contents will occur. Flour (sugar, etc.) sacks should be loaded with the filling end up.

Every load should be securely lashed, and if the truck is not covered, a tarpaulin should be placed over the load as a protection against the sun, dust or rain. The required equipment for every truck is two 60-foot lash lines, which should be sufficient to lash an ordinary cargo. There is an additional equipment of 150 feet of 1½ inch rope in every train or command.

THE HAULING OF CARGO.

A top-heavy load is always dangerous, but in ruts and on corduroy roads, it is a menace. An overturned truck may block a vitally important road. A truck with a load wider than the prescribed limit is a danger, as it is probable that it will be too wide to pass large vehicles on narrow roads. Corduroy roads are common in various regions, and the truck driver must learn to be master of his truck while driving over the logs that make up such roads. Although fastened with stakes, a loose log is not an uncommon obstacle and its presence may throw a vehicle from the road. If a truck keeps

squarely on the corduroy road, it is not subject to skidding. However, once off the road, a truck is not easily recovered. Slow, constant speed is the first essential for safe operation under these conditions. The front wheels may catch against a loose log or in a crevice and swerve the vehicle to one side and off the road.

The handling of trucks at all loading places calls for similar precaution, as a skid, collision, or overdrive into mud or sand can tie up a badly needed vehicle—perhaps an entire section. Considerable backing is necessary in all loading. Consequently the truck driver and his assistant should become proficient both in the handling of the wheel and in the execution of signals.

Actual loading or unloading operations should never be allowed to interfere with the handling of a convoy. Truck drivers or assistants are not to engage in any handling of cargo. But, although the personnel of a convoy does not actually handle goods, it is the duty of those in charge of trucks and sections to oversee loading and to require that goods are properly loaded into vehicles and securely lashed.

Whenever possible, information regarding the road to be traveled should be gathered and, if necessary, extreme precautions taken in loading, lashing, and operation.

SPECIAL LOADING CONSIDERATIONS.

After conferring with the various manufacturers and others interested in the loading of materials, they give as a general rule that 60 to 80 per cent of the load should be carried by the rear axle.

Lumber should be loaded with heavy timbers at the bottom, working up with lighter material. The method followed is to place stakes of flat material, such as 2 by 4s (cut to the desired loading height), around the bed every 3 feet from front to back. These supports will stay the load. They are placed inside and against the side of the bed and held in place by the loaded lumber. Stakes must never be nailed, but should be securely lashed.

Boxed goods will be found in cases of various sizes and shapes. The method followed is to place large and heavy boxes at the bottom and to the rear, building up until sufficiently high to ride. The load or capacity weight should not be exceeded.

Baled goods, consisting of hay, straw, blankets, canvas, and occasionally clothing, will come in various sizes and weights. Loads must be confined to beds of trucks and never be extended over the sides. When the end gate is chained flush with the floor the load may extend beyond the bed length. The longer bales are loaded first, and, when rising above the bed, should be slanted pyramid style and as close together as possible.

Sacked goods are principally forage and food supplies. Extreme care should be employed in loading, handling, and transporting such material to prevent shifting on rough roads. When the bed has been filled the sacks should be pyramided until there is but a single row on the top parallel to bed length. Such a load should be lashed and covered with special care.

Barreled goods are difficult to load, especially when there is no specially constructed bed. If headed, barrel on barrel, until the

top of the bed is reached, they should then be pyramided in such a way as to allow the barrels to fit in a row of two's and cover a line between the two of the layer below. Unheaded barrels, or barrels covered only with burlap, should be stood on end and carefully lashed. A load of unheaded barrels is of course materially lighter than one of headed barrels.

Bundles will be found to consist principally of canvas. The loading of this material is comparatively simple. With large bundles first, pyramided after bed line is reached, such a load will ride well.

Crated goods consist of hardware and food supplies and must be loaded with heavy goods at the bottom and to the rear of the truck, with light fragile crates on top.

Loose material presents the greatest loading problem. Such material is usually hardware, farm implements, and such items as cans, wheelbarrows, trench walks, rolls of barbed wire, coils of spring wire, dugout material, and principally semielliptic corrugated iron about 10 feet in diameter. Mixed loads prevail in handling loose material and must be made up according to the nature of the material on hand. The use of much common sense is the only rule that can be laid down. Every bit of available space should be utilized without overloading.

INSTRUCTIONS FOR HANDLING AMMUNITION.

In handling all types of ammunition, care must be taken that crates are not broken or, if uncrated, that the copper bands at base of shells are not scratched or deformed.

Damaged bands render the shells not only useless but dangerous to fire.

Do not allow colors painted on shells to be effaced. They were put there for a purpose and are necessary.

Protect ammunition from sun and rain; both are harmful to the high explosive filling.

When fuses are attached to shells, do not handle by fuses; you may destroy the protective cover and ruin the fuse. Where fuses are not attached, plugs replace them. Should one of these fall out, put it back at once.

When handling gas shells, be provided with a mask to protect against leaky shells.

All ammunition is highly explosive, therefore dangerous. Do not smoke while moving it, and *handle with care*.

Overloading should be carefully avoided. The greatly increased wear on tires, the breakage of springs, and the strain to which all parts of the mechanism and chassis are subjected greatly outweigh any advantage gained by handling more material and making fewer trips.

LASHING.

Equipment for lashing loads on trucks consists of the two 60-foot lengths of rope provided, and the lash hooks or rings through which to pass the lines. After the first tie at the front side has been made, a rope is passed over the top of the load (adjusted to pass over some

article which binds goods beneath it) and brought down on the opposite side. It is not brought through the hook or ring directly opposite the other side, but the one just back or to the rear of it. The rope is then brought back over the top. This process is repeated until the rear of the truck has been reached. It should be borne in mind that only every other hook or ring is used in attaching.

When this process is completed, the extra rope is used, starting at the opposite side, and criss-crossed to the rear of the truck to effect the same operation as with the first rope. This rope also is attached only to every other hook or ring. The load will so bind that nothing less than a complete turnover will spill it, provided, of course, that it is correctly stacked.

RIGHTING OVERTURNED TRUCK.

It is not unusual for a truck to turn over, either through faulty loading or from unavoidable causes, especially on bad roads at night.

In the event of a turnover, only that part of the load that has broken away from the lashings is to be removed. Directly opposite the middle of the vehicle and about 30 feet away, two stakes of convenient materials are driven about 4 feet apart. Block and tackle are attached by means of a bridle. One block is attached to stake, and the other to the two wheels in the air. If using single and double blocks, the single block is attached to the stakes and the double attached to the vehicle. Mechanical, horse or hand power is effective.

The following list of engineers' supplies and ammunition gives some idea of the materials to be carried. A table of weights is also supplied to give the student an idea of the relative weight of various articles and the quantity that may be, with safety, loaded into a truck:

Quantities which can be loaded into motor trucks.

MISCELLANEOUS.

Articles.	How packed.	Loaded and lashed.		
		1½ tons.	3 tons.	5 tons.
Gasoline tanks.....	50 gallons, full.....	350 gal. 7	700 gal. 14	1,350 gal. 27
	50 gallons, empty.....	16	30	30
	13 gallons, full.....	390 gal. 30	650 gal. 50	988 gal. 76
	13 gallons, empty.....	81	125	125
Tires, pneumatic.....	Assorted sizes.....	75	150	150
Mail bags.....		30	50	60
Tarpaulins.....		25	50	70
Barrack bags.....		25	50	70
Trunks, Army.....		30	60	60
Men.....	Baggage.....	12	20	25
Do.....	Without baggage.....	18	35	35

Quantities which can be loaded into motor trucks—Continued.

ENGINEER STORES.

	1½-ton truck.	3-ton truck.	5-ton truck.
Barracks, "Adrian" (21 by 98 feet).....		$\frac{1}{2}$	$\frac{1}{2}$
Bricks.....	750	1,500	2,500
Camouflage, finished, rolls of 20 square yards.....	80	100	120
Cracked stone, cubic yards.....	$1\frac{1}{2}$	3	5
Cement, barrels (4-100 pound bags).....	12	24	30
Corrugated iron, sheets, square feet.....	1,200	3,000	3,000
Duck boards (6 feet 6 inches by 1 foot 6 inches).....	100	150	150
Expanded metal, large mesh, square feet.....	1,600	2,500	2,500
I-beams, 4-inch, 12 feet long, pieces.....	40	80	110
I-beams, 6-inch, 16 feet long, pieces.....	20	40	65
Lumber, feet b. m.....	800	1,600	2,500
Nails, all sizes, 100-pound kegs.....	30	60	80
Paint, 50-gallon barrels.....	4	9	14
Pickets, wood, 50 per cent long and 50 per cent short.....	350	500	500
Posts, angle iron (50 per cent 5 feet 10 inches long).....	500	1,000	1,700
Posts, angle iron (50 per cent 3 feet 6 inches long).....	500	1,000	1,700
Posts, screw, 50 per cent long and 50 per cent short.....	700	1,400	2,400
Rails, 10 to 12 feet long, 25 pounds per yard.....	40	80	110
Rails, 15 feet long, 35 pounds per yard.....	20	40	70
Revetting, fascines, 10 inches by 9 feet.....	30	35	35
Revetting, gabions, 2 feet by 3 feet 2 inches.....	25	32	32
Revetting, hurdles, 7 feet 3 inches by 3 feet 2 inches.....	50	75	75
Road planks, 5 inches by 9 inches by 9 feet.....	30	60	100
Roofing felt (216 square feet, rolls).....	80	130	130
Sand bags, number.....	10,000	15,000	15,000
Shelters, steel, large, complete.....	1	2	2
Shelters, steel, small, complete.....	2	2	2
Round posts, 6-inch, rough, linear feet.....	300	600	1,000
Tar, waterproofing, 50-gallon barrels.....	10	20	24
Ties, for narrow gauge, 4 feet 6 inches by 6 inches by 4 inches.....	80	160	260
Telephone conduit cable spools.....	1	2	3
Wire, barbed, 50-pound rolls.....	60	60	60

Quantities which can be loaded into motor trucks—Continued.

QUARTERMASTER STORES.

Articles.	Unit.	Not lashed.			Lashed.			3-ton truck, 12 feet by 6 feet 6 inches by 2 feet.			5-ton truck, 12 feet by 6 feet 6 inches by 2 feet.		
		Number units.	Tons weight.	Number units.	Number units.	Tons weight.	Number units.	Number units.	Tons weight.	Number units.	Number units.	Tons weight.	Tons weight.
Rations.....	Box.....	46	1½	46	1½	72	2½	84	3	72	2½	130	5
Beans.....	do.....												
Flour.....	do.....												
Potatoes.....	Bag.....	36	1½	30	1½	60	3	60	3	100	5	100	5
Rice.....	do.....												
Sugar.....	Bag.....	33	1½	33	1½	66	3	66	3	110	5	110	5
Commeal.....	Barrel.....	10	1	15	1½	18	1½	28	2½	18	1½	28	2½
Ham.....	do.....	12	1	20	1½	18	1½	38	2½	18	1½	38	2½
Vinegar.....	do.....	26	1½	26	1½	60	3	60	3	60	3	60	3
Hay.....	Bag.....	26	1½	26	1½	50	2½	50	2½	50	2½	50	2½
Oats.....	do.....												
Wool fire (green).....	Cord.....	22	1	36	1½	36	1½	60	1½	36	1½	60	1½
Blankets.....	do.....	22	1	36	1½	36	1½	60	1½	36	1½	60	1½
Clothing.....	do.....	22	1	36	1½	36	1½	60	1½	36	1½	60	1½
Cots.....	do.....	22	1	36	1½	36	1½	60	1½	36	1½	60	1½
Axe.....	do.....	66	1½	60	1½	120	3	120	3	200	5	200	5
Helves (axe).....	do.....	24	1	30	1½	31	1½	90	3	31	1½	175	3½
Helves (pickaxe).....	do.....	35	1½	45	1½	47	1½	90	3	47	1½	175	3½
Pickaxe.....	do.....	20	1	20	1	40	3	40	3	40	3	40	3
Shovel.....	do.....	86	1½	86	1½	140	3½	178	3	140	3½	200	3½
Top pyramid.....	do.....	1½	1½	26	1½	24	1½	52	3	24	1½	52	3
Coal.....	Tons.....	9	1½	3	1½	3	1½	3	1½	3	1½	3	1½

Quantities which can be loaded into motor trucks—Continued.
ORDNANCE STORES (AMMUNITION).

Size.	Article.	Maximum load for one truck.			Remarks.
		1½-ton, 10 feet by 5 feet 1 inch by 2 feet.	3-ton, 12 feet by 6 feet 6 inches by 2 feet.	5-ton, 12 feet by 6 feet 6 inches by 2 feet.	
37-mm.....	Complete cart.....	1,800 (30 cases).....	4,020 (67 cases).....	5,760 (96 cases).....	Cases on bottom.
	Fuse.....				
75-mm.....	Complete cart.....	135 (15 cases).....	261 (29 cases).....	432 (48 cases).....	Do.
	Fuse.....				
4.7-inch gun.....	Complete cart.....	50 (25 cases).....	102 (51 cases).....	170 (85 cases).....	Do.
	Fuse.....				
5-inch seacoast gun.....	Shell.....	52 loose or 12 cases.....	104 loose or 24 cases.....	172 loose or 40 cases.....	Shell on end cases flat.
	Fuse.....				
	Charge.....				
	Primer.....	166 (wt. full).....	333 (wt. full).....	500 (space full).....	Cartridge on end.
155-mm.....	Shell.....	32 loose or 13 cases.....	63 loose or 27 cases.....	115 loose or 45 cases.....	Shell on end cases flat.
	Fuse.....				
	Charge.....	150 cases (wt. full).....	250 cases.....	250 cases (space full).....	Cartridge on end.
	Primer.....				
6-inch seacoast gun.....	Shell.....	33 loose or 11 cases.....	66 loose or 22 cases.....	110 loose or 37 cases.....	Shell on end cases flat.
	Fuse.....				
	Charge.....	75 cases (wt. full).....	150 cases (wt. full).....	187 cases (space full).....	Cartridge on end.
	Primer.....				
8-inch seacoast gun.....	Shell.....	15 loose or 13 cases.....	30 loose or 27 cases.....	50 loose or 44 cases.....	Shell on end cases flat.
	Fuse.....				
	Charge.....	26 cases (wt.).....	48 cases (wt.).....	51 cases (space).....	Containers on end.
	Primer.....				
8-inch howitzer.....	Shell.....	15 loose or 13 cases.....	30 loose or 27 cases.....	50 loose or 44 cases.....	Shell on end cases flat.
	Fuse.....				
	Charge.....	26 cases (wt.).....	48 cases (wt.).....	51 cases (space).....	Containers on end.
	Primer.....				

FIELD OPERATIONS.

LECTURE VIII.

CONVOY PROBLEM.¹

The following problem is given as a simple example of conditions to be found and situations to be met in motor transport work.

The commander of the 20th Motor Transport Company at Two Taverns, operating 3-ton trucks, is giving the following transport order at 9 p. m. August 20, 1919.

MOTOR TRANSPORT ORDER.

Order No. 25; date, August 20, 1919.

From commanding officer, 4th Motor Transport Train.

To commanding officer, 20th Motor Transport Corps.

You will furnish motor transportation as follows:

Number of vehicles.	Report for loading.			To transport tons.	Report for unloading.			Route and remarks.
	To (place).	At (time).	To (officer).		To (place).	At (time).	To (officer).	
Two taverns.		8.10 a. m. Aug. 21.	Commanding officer Companies G and H, 10th Infantry.	2 companies Infantry, 500 men.	Round Hill.	5 p. m. Aug. 21.	Commanding officer 2d Battalion, 10th Infantry.	Load with salvage at Round Hill and deliver same to salvage plant, Gettysburg, on Aug. 22. Bridges north of Newchester not passable by trucks.

Date of execution of order, August 21 and 22, 1919.

Total number of vehicles.

Order received at (Place) Cemetery Hill.

(Time) 9 p. m.

(Date) August 20, 1919.

Signed J. Smith.

Rank First Lieutenant, Motor Transport Corps, commanding 20th Motor Transport Corps.

(Signed) Geo. Brown.

Rank, Captain, Motor Transport Corps.

¹To be solved on Gettysburg map United States Geological Survey. Scale of map is assumed to be three miles to the inch for convenience in handling a single map.

minutes allowed him in which to cover this distance; that is, from 8.10 a. m. to 5 p. m. He allows one-half hour for loading troops and 1 hour to stop for dinner, leaving 7 hours and 20 minutes actual running time, or something less than 8 miles per hour.

He now considers the question of feeding his men. Since he will be gone nearly two days and overnight, he decides to take the kitchen trailer to insure proper issue of hot food to the command.

He therefore about 10 p. m. issues a company transport order to his truckmaster in the following form:

COMPANY TRANSPORT ORDER.

Order No. 18, Truck Company No. 20, date: *Aug. 20, 1919.*

1. Date of mission, August 21.
2. Nature of mission, troop convoy.
3. Number of trucks, 26 (1 empty).
4. Truck numbers, all trucks except No. 47126 and kitchen trailer.
5. Guide, Sergt. Peters.
6. File closer, Sergt. Williams.
7. Second section, Sergt. James.
8. Third section, Sergt. Gibbs.
9. Starting hour, 6.30 a. m.
10. Itinerary (empty), Baltimore Pike to Two Taverns.
11. Loading point, Two Taverns.
12. Loading hour, 8.10 a. m.
13. Nature of load, 500 men (2 companies Infantry).
14. Tonnage or number of men per truck, 20.
15. Itinerary (with load), Two Taverns, Bonneauville, 593, 573, York Pike, Brush Run, New Oxford, 581, C. and B. Pike to Round Hill.
16. Unloading point, Round Hill.
17. Itinerary (return), C. and B. Pike, York Pike to Gettysburg to Cemetery Hill.
18. Remarks (covering meals—Refilling): Stop for dinner east of New Oxford; supper and breakfast August 21, at Round Hill; load with salvage at Round Hill on August 22 and deliver same at salvage plant, Gettysburg; fill trucks with gas and oil before leaving. One tank truck, filled, will leave camp at 8 a. m. August 22, and meet convoy at Brush Run on York Pike.

Signature J. SMITH,
First Lieutenant, Motor Transport Corps.

This order covers in a uniform and systematic way all necessary details for the movement. It indicates to the truckmaster all the things that he must arrange for, and he sees that all the necessary minor duties are performed by all the various members of the company concerned, such as the assistant truckmasters, cooks, etc.

The company commander arrives at the park about 6 a. m., August 21, makes an informal inspection of everything, sees that the guide has the itinerary correctly, starts him off at 6.30, sees that the other trucks follow at proper intervals, and himself falls in at the end of the column (see Lecture III, General Principles of Convoy).

FIELD OPERATIONS.

LECTURE IX.

KNOTTING AND SPLICING.

It is suggested that a board of the various knots, tied, attached, and labeled for instruction purposes be used.

The art of working in rope can not be learned from a book, but the illustrations which follow are used to give an idea of the most common knots and splices of value to truck operators and should be studied and mastered.

There are three qualities to a good knot :

1. Rapidity with which it can be tied.
2. Its ability to hold fast when pulled tight.
3. The readiness with which it can be undone.

To understand clearly the explanations and descriptions of the various knots, one must have clearly in mind the principal parts of a rope (see fig. 1) :

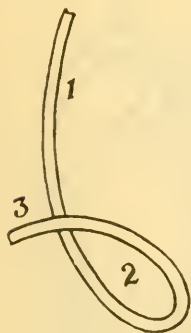


FIG. 1.



FIG. 2.

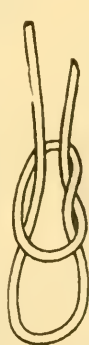


FIG. 3.



FIG. 4.

(1) The standing part—the long unused portion of the rope on which he works.

(2) The bight—the loop or hitch formed whenever the rope is turned back upon itself, and

(3) The end—the part he uses in leading.

The following knots are most commonly in use by truck drivers :

Fig. 2. *Square or reef knot*.—The commonest for tying two ropes together. Never slips or jams; easy to untie.

Fig. 3. *Slip or running knot*.—A bight is first formed and an overhaul knot made with the end around the standing part.

Fig. 4. *The bowline*.—A noose that neither jams nor slips. Form a small loop on the standing part leaving the end long enough for the size of the noose required. Pass the end up through the bight,

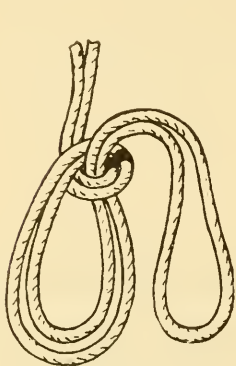


FIG. 5.



FIG. 6.

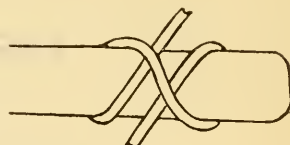


FIG. 7.



FIG. 8.

around the standing part, and down through the bight again. To tighten, hold noose in position and pull standing part.

Figs. 5 and 6. *Bowline on a bight*.—Used in place of a single bowline where greater strength is needed.

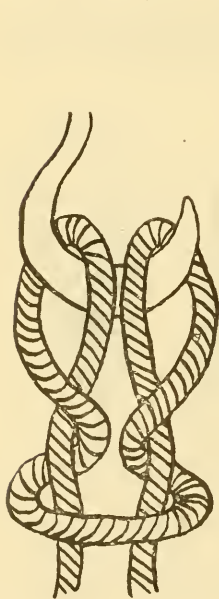


FIG. 9.—Cat's-paw.

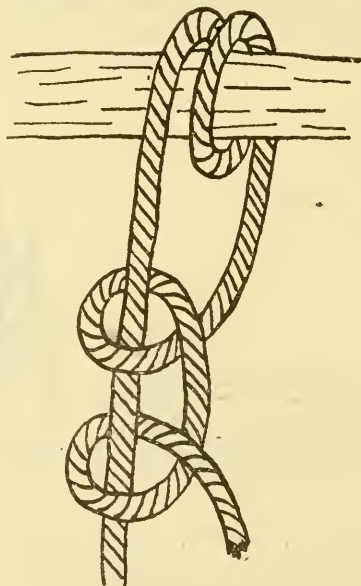


FIG. 10.—Round turn and two half hitches.

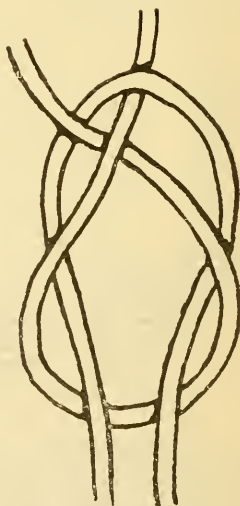


FIG. 11.—Sheet bend or weaver's knot.

Fig. 7. *Clove hitch*.—Used to fasten one pole to another; this knot holds snugly and is not liable to slip laterally. Hold the standing part in left hand, then pass the rope around the pole, across to the standing part, making a second turn around the pole, and pass the end under the last turn.

Fig. 8. *Two half hitches*.—Useful because they are easily made and will not slip under any strain. Their formation is sufficiently indicated by the illustration.

Fig. 9. *The cat's-paw*.—Can be used when both ends of the rope are not available. It will not slip.

Fig. 10. *Round turn and two half hitches*.—This may be used around an axle.

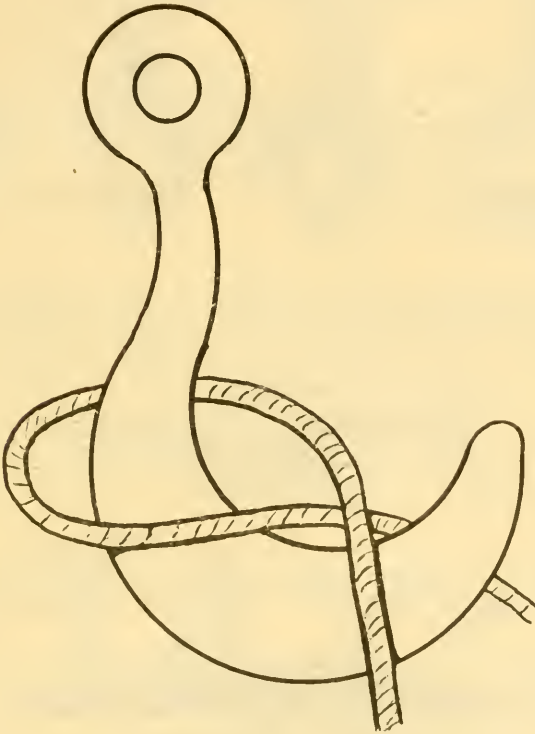


Fig. 12.—Blackwall hitch.

Fig. 11.—*Sheet bend or weaver's knot*.—Used in tying two rope ends together. Make a bight with one rope AB, then pass C of the other rope up through and around the entire bight and bind it under its own standing part.

Fig. 12. *Blackwall hitch*.—Used to secure a rope to a hook. The standing part when hauled tight holds the ends firmly.

Splicing is joining the ends of two ropes permanently or bending back the end of a rope upon itself to form a permanent eye.

The following are the few methods of splicing in use:

SPLICING.

1. *Eye splice (stranded rope)* (figs. 13-16).—The rope is unlaid for perhaps a foot from the end, and the strands brought back upon the body of the rope at a point which will form an eye of the size that is

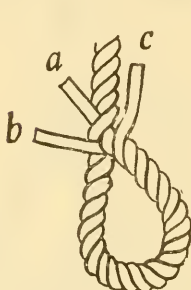


FIG. 13.

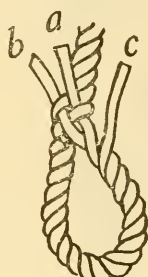


FIG. 14.

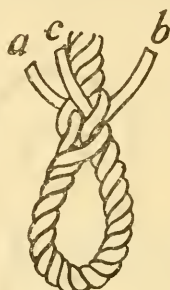


FIG. 15.



FIG. 16.

desired. Beginning with any one strand, this is tucked from left to right through the strands of the rope, being passed over one and under the next. The other strands are similarly tucked always from

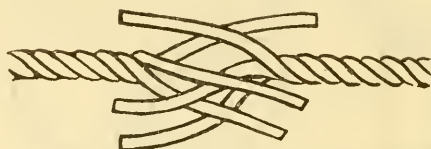


FIG. 17.

right to left. All are then trimmed down to two-thirds their original size, tucked again, trimmed to one-third size and tucked a third and

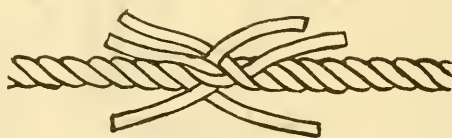


FIG. 18.

last time (see illustration). Where the rope is of four strands, the first strand is tucked under two; but this for the first tucking only.

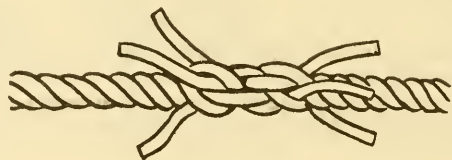


FIG. 19.

2. *Short splice* (figs. 17-19).—Two ropes are unlaid for a short distance and married together with strands interlacing. The strands are then tucked through the lay of the other rope exactly as has been described in the case of an eye splice.

3. *Long splice* (figs. 20-21).—Here the ropes are unlaid for a greater distance than for a short splice, and the ends brought together as before, with strands interlacing. Instead now of tucking at once, we proceed as follows (see illustration): Unlay a-1, one of the strands of A, for a considerable distance, and in place of it lay up b-1 the adjoining strand of B, thus working a strand of B into A, for, say, a foot and a half or two feet. For convenience now twist up a-1 and b-1 together temporarily, as illustrated. Turn the rope

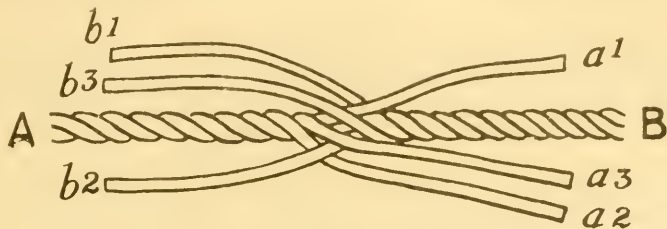


FIG. 20.—Eye splice.

end for end, unlay b-2, one of the strands of B, and in place of it lay up a-2, the adjoining strand of A, a-3 and b-3 are left lying beside each other without being unlaid. We now have three pairs of strands at different points of the rope. Beginning with a-2 and b-2 (for example) separate each strand, overhand knot these together and tuck them as in a short splice, over one and under one of the full remaining strands of the rope. The other pairs of strands (a-1 b-1) (a-3 b-3) are similarly reduced, knotted, and tucked. The spare

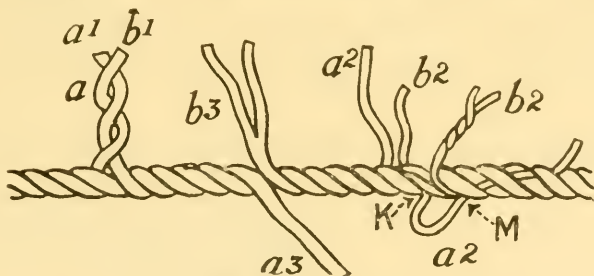


FIG. 21.—Long splice.

half of each strand is trimmed off smooth as are the ends of the other halves after they have been tucked.

Rope is measured by its circumference. A four-strand rope is about one-fifth weaker than a three-strand one. Blocks should be at least three times the size of the rope which it is intended to serve in them. The hauling part bears twice the strain of the standing part of a fall.

Breaking strains.—Square the circumference and divide by 3 for the breaking strain in tons; divide by 9 for the proof strain, by 6 for the working strain.

FIELD OPERATIONS.
LECTURE X.
TECHNICAL INSPECTION.

Technical inspection of motor equipment will be made under the direction of a company officer and the mechanic and at periods when it is most convenient to do the work without interfering with the routine truck details. Inspection of all the equipment will be made at intervals not to exceed 10 days.

No repairs should be sent to the shop which can be properly made by the company mechanics. If this is carefully checked, much time may be saved, as the truck would not remain idle in the shop.

The following list will indicate the general questions that must be satisfactorily answered in a thorough inspection:

TECHNICAL INSPECTION.

COOLING SYSTEM.

Radiator:

- (a) Are there any leaks?
- (b) Will water flow from drain cock? If so, is it very full of sediment?
- (c) Is the passage of air through the radiator obstructed by dirt, etc.?
- (d) Is the filter in position, and the overflow pipe clear?

Hose connections:

- (a) Do any of the connections leak?
- (b) Do any of the connections show wear and need replacing?

Circulation:

- (a) Is the fan in good working order?
- (b) Is the belt in good condition?
- (c) Is the fan bracket tight?
- (d) Does water circulate freely? (Take radiator cap off while motor is running and observe circulation.)
- (e) If equipped with thermostat, does it function?
- (f) Does pump leak around shaft?

MOTOR.

Compression:

- (a) Test the compression by switching off the ignition and slowly cranking by hand. Open all the compression cocks except the one on the cylinder being tested. Test each cylinder in turn, always pulling up on crank to feel the compression. This should be done when the motor is warm.
- (b) Examine cylinder head joint (if detachable head motor), valve cap plugs, and pet cocks for leaks.

Valve adjustment:

- (a) Test tappet settings for proper adjustment. See vehicle manufacturer's instruction book for the proper clearance. To test clearance, have engine revolved slowly until tappet is in its lowest position, try different leaves of a "feeler gauge" between the tappet and valve stem, the leaf that "just goes" is the amount of clearance. Do not report in detail; simply state "O. K." or "to be readjusted."

Governor:

- (a) If a vehicle has a governor, is it in working order? The condition can best be determined by driving or road test.
- (b) Does governor show signs of having been tampered with?

Carburetor:

- (a) Does the float overflow?
- (b) Does the motor idle at proper speed?
- (c) Are the gas connections tight?

Controls:

- (a) Examine ball joints and yoke and pin joints of spark and throttle controls for lost motion and proper functioning.

Oiling system:

- (a) If pressure system, does the dash pressure gauge show proper pressure when motor is running?
- (b) Check oil level in crank case.
- (c) Is oil in crank case in good condition and free from grit? Is the proper grade being used?
- (d) Is oil filter in position and clean?

General:

- (a) Are all bolts tight?
- (b) Examine crank-case arms for cracks.
- (c) If engine is suspended from support beams, are the brackets tight? Is the support pin worn?
- (d) Does engine "knock" from carbon?
- (e) Does the engine "knock" from loose bearings?
- (f) Does the starting crank engage and disengage properly?

IGNITION AND ELECTRIC SYSTEM.

Magneto:

- (a) Is the distributor clean?
- (b) Is the breaker box clean?
- (c) Test the magneto by disconnecting the cable from one spark plug at a time and holding the end of the same approximately $\frac{1}{4}$ of an inch from some unpainted metal part and observe whether or not spark jumps the gap while the engine is running.
- (d) Is the coupling in good condition?

Cables:

- (a) Examine the high and low tension cables for broken insulation or signs of wear on the same.

Spark plugs:

- (a) Have spark plugs removed and examine them for proper setting, cleanliness, and cracked or broken porcelains.

Generator:

- (a) Ascertain if the generator is operating properly by observing the volt meter or ammeter while the engine is running. Also check the approximate speed of cut-in and cut-out. See manufacturer's instruction books for details concerning the generator.
- (b) Are the wire connections on the generator tight?
- (c) Is the commutator clean?

Starting motor:

- (a) See that wire connections are tight and try the motor for correct operation.

Battery:

- (a) Test the condition of the battery with a hydrometer. Gravity between 1.275-1.300 indicates battery in a fully charged condition. Gravity between 1.200-1.275 indicates battery is more than half charged. Gravity below 1.200 but above 1.150 indicates battery less than half charged. Gravity below 1.150 indicates that the battery is in a run-down condition.
- (b) Are the battery holding down devices tight?
- (c) Is the battery electrolyte up to the proper height?
- (d) Is the battery clean?
- (e) Are the battery terminal connections tight? Are they corroded?

Instruments:

- (a) Examine the dash instruments for condition and operation.

Wiring:

- (a) Examine the wiring connections for tightness.
- (b) Does insulation show wear?
- (c) Are proper fuses in place?

FUEL SYSTEM.

Gasoline tank:

- (a) Are the fastenings tight?
- (b) Examine the tank for leaks.

Gasoline lines:

- (a) Examine all fittings for leaks.
- (b) Are the lines properly supported?

TRANSMISSION SYSTEM.

Clutch:

- (a) Does the clutch disengage freely and properly?
- (b) Are the disengaged thrust faces and disengaging fork fingers badly worn?
- (c) Is the lubrication proper?
- (d) If a cone clutch, is the leather in good condition: if disk, are the disks in good condition?
- (e) Are the pedal shaft bushings badly worn? Is the action of the pedals correct?
- (f) Is the clutch brake effective?

Gear box:

- (a) Does the case show any signs of cracks or oil leaks?
- (b) Are the bolts which hold it in position loose or worn?
- (c) Is the lubrication of the proper type and at the proper height?
- (d) Do the gears engage and disengage freely? If the gears do not engage freely or if trouble has been experienced by the driver with the gears not remaining in mesh, the transmission case cover must be removed and the gears and bearings examined.

Controls:

- (a) Examine the change gear mechanism for wear and proper lubrication.

Universal joints:

- (a) Are all universal joints properly lubricated?
- (b) Are the dirt protectors in good condition?
- (c) *Do any of the universal joints show signs of excessive wear?

Differential:

- (a) Examine the housing for cracks and oil leaks.
- (b) Are all joints and bolts tight?
- (c) Is the truss rod tight?
- (d) *If the vehicle is worm drive, does the worm have excessive end play (more than approximately $\frac{1}{16}$ inch)?
- (e) **Does the differential function freely and smoothly?
- (f) Is the lubrication of proper type and at proper height?
Examine some of the lubricants, drawn from the bottom of the housing for metal chips.

NOTE.—To test points marked (*) have one wheel jacked up and the other blocked. Put lower gear on mesh with clutch engaged and have wheel which is jacked up rotated forward and backward. To test point marked (**) disengage clutch and proceed as in (*) case except have wheel revolved first in one direction and then in the other.

Shafts and chains:

- (a) Do slip joints, if any, show excessive wear?
- (b) Are all couplings tight?
- (c) If previous trouble has been experienced with live axles breaking, have the axles removed and examine for any signs of twisting.
- (d) In case of chain drive trucks:
 - (d-1) Are chains properly adjusted?
 - (d-2) Are the sprockets badly worn or loose?
 - (d-3) Do the chains show excessive wear?
 - (d-4) Are the chains properly lubricated?

VEHICLE CONTROLS.

Steering gear:

- (a) Is the wheel play excessive?
- (b) Is the steering gear housing tightly bolted to the frame?
- (c) Is the lubrication ample and proper?

Steering gear connections:

- (a) Are the drag link spring ball joints properly adjusted, lubricated and provided with covers?
- (b) Are the steering connecting rod yoke pins and bushings worn? Are they properly lubricated?
- (c) Are the wheels properly lined up?

Hand brakes:

- (a) Are the drums tight on the wheels, or if propeller shaft brake, is the drum tight on the shaft?
- (b) Do the brakes release fully?
- (c) If a lined brake, is the lining in need of renewal? If not lined, are shoes badly worn?
- (d) If shoes are used do they grip the drum properly and are they properly centered? Are the shoe pins free and lubricated?
- (e) Does the equalizing mechanism work properly and do brakes grip equally? This fact can be best determined on road test by observing rear wheels at time of sudden stops. Positive gripping of one brake shoe will be reported without fail, as this has a very harmful effect on the tire.
- (f) Is the brake operating mechanism, cam, or toggle worn? Is it properly lubricated? Are the operating shafts free and well lubricated? Are the bushings worn?
- (g) Are the rod yoke pins worn? Are they lubricated?
- (h) Is the hand brake ratchet worn?
- (i) Are the releasing springs in working order?

Foot brakes:

- (a) Are pedal shaft bushings worn?

FRONT AXLE.

Knuckle bearings:

- (a) Are the knuckle bearings or bushing worn? If roller bearings are used, is the adjustment correct?
- (b) Is the lubrication ample? Are the lubricators broken or lost?

Wheel bearing adjustment:

- (a) Are the bearings in good condition and is the adjustment proper? Roller bearings should have a small amount of end play when cold in order to take care of expansion from normal heating. The correct adjustment is to draw the retainer nut up and then back off one-fourth of a turn before setting the cotter. In order to test a bearing adjustment, the inspector must familiarize himself with the feel of a properly adjusted like bearing and judge by comparison. On the heavier trucks it will be necessary to jack up the wheel to make final decision.
- (b) Is the lubrication ample?
- (c) Are both hub caps tight?

Springs:

- (a) Are there any broken leaves?
- (b) Are any clips broken or missing?
- (c) Are the shackle pins or eyes worn?
- (d) Are the shackles well lubricated? Are any lubricators missing?
- (e) Are the springs rusted between leaves?
- (f) Are the springs to axle bolts tight?

REAR AXLE.

Wheel bearing adjustment:

(a), (b), (c), same as (a), (b), (c) under "Wheel bearing adjustment," above.

(d) Is the lubricant from wheel bearing leaking onto the brakes?

Torque arm:

(a) If the torque arm has a bearing at the rear, is it worn; is it free or frozen; is it well lubricated? If it has no bearing at rear end, is the means of fastening it on the rear axle housing tight?

(b) Is the front end support mechanism worn? Is it lubricated? If a spring mechanism is used at the front, are the springs properly adjusted?

(c) Does the torque arm show any cracks developing or loose rivets, etc.?

Distance rods:

(a) Are the bushings at either end frozen or worn?

(b) Are they well lubricated at both ends? Are any lubricators missing?

Springs:

(a), (b), (c), (d), (e), same as (a), (b), (c), (d), (e) under "Springs," above.

(f) If the spring chair is bushed on the rear axle housing, is it frozen? Is the lubrication proper? Has the spring chair developed any cracks?

(g) Are the bolts holding down the springs tight?

(h) If provided with center pins are they sheared off?

(i) If provided with center band, is it cracked?

TIRES AND WHEELS.

Tires:

(a) Do tires need replacement?

(b) Are they loose on the wheels?

(c) If pneumatic, are they properly inflated?

(d) If solid, condition and appearance of cuts, runners, and snipping.

(e) Do the tires show signs of excessive wear caused by wheels being out of alignment or by under inflation?

(1) Are wheels in good condition?

(2) Spokes tight?

(3) Spokes cracked or broken?

(4) Hub bolts tight?

CHASSIS.

Frame:

(a) Is frame bent in any place?

(b) If provided with a strut rod, is it tight?

(c) Are there any cracks developing (especially about center)?

Brackets:

(a) Are there any signs of fracture?

(b) Are all bolts or rivets, holding to the frame, tight?

Bumpers:

- (a) Are rear bumpers, if provided, in good condition and tight on frame?
- (b) Are front bumper springs broken? Are all parts tightly bolted and in good condition?
- (c) Is radiator guard in good condition?

Mud guards:

- (a) Are any badly bent, broken, or missing?
- (b) Are rivets or bolts from mud guard to brackets tight? Are bolts from brackets to frame tight?

Towing hooks:

- (a) Are hooks or springs broken?
- (b) Are fastenings to frame tight?

BODY.

Seat and dash:

- (a) Is the superstructure securely held to the frame?
- (b) Are the seat and cushions in good condition?
- (c) Is the dash broken or cracked?
- (d) Are the lamp brackets tight?

Top:

- (a) Is the seat top in good condition?
- (b) Is the body tarpaulin sound and water-tight? Is it correctly lashed down?

Body:

- (a) Are the bolts and brackets which hold the body to the chassis broken or loose.
- (b) Is the tail gate broken? Are any tail gate chains missing or broken?
- (c) Are any body chains broken?
- (d) Does body need any carpenter work?
- (e) Is the tool box in good condition?
- (f) Are the troop benches in good condition?
- (g) Is the inside of the body clean?

EQUIPMENT.

Tools:

- (a) Any shortage against standard list?
- (b) General condition of tools?
- (a) Any shortage against standard list?
- (b) General condition of accessories?

Accessories:

SPECIAL NOTES.

In making out inspection report, enter under "Remarks" any points not covered in the body of the report. The outline of points to be inspected, given above, is intended as a guide and does not necessarily cover all points which may come up at inspection.

GENERAL CONDITIONS.

Under "General condition" the inspector will enter a statement concerning the vehicle as a whole and any comments which he thinks advisable to note concerning the way it is cared for and operated.

RATE SYMBOL.

The same symbol as entered on the inspection chart will be placed very plainly in the lower left-hand corner of the inspection report. It is very important that this be done and that the instructions on sample instruction chart be followed for determining the symbol to be used.

The driver will enter in the Log Book of the vehicle the date inspection was made and the rate symbol, and sign the same.

MOTOR TRANSPORT CORPS
R. O. T. C. UNIT

CONVOY PRACTICE
OUTLINES

SCHEDULE OF CONVOY EXERCISES.

GENERAL STATEMENT.

The following exercises in "Convoy" presuppose that the students are able to drive the vehicles with reasonable facility.

The instructor should ascertain, by road trial, which students are able to drive, and take steps to provide instruction in elementary driving for the other students, far enough in advance of the regular convoy instruction to have all students able to drive before the convoy exercises start.

FIRST EXERCISE.

Stationary field drill illustrating distances and formations.

Method of cranking motors with left arm.

Position of driver and assistant driver.

Space trucks to illustrate distance between trucks and sections in open and close formation. Have men sight on some part of truck ahead to use as gauge for proper distance. Explain about getting distance from truck ahead and speed from truck behind.

Give and practice signals for attention, crank motors forward and halt.

Go through drill of assistant drivers coming to attention upon hearing whistle signal and insist that they all jump from their seats at the same time and land on the ground in their proper positions simultaneously and in a uniform manner.

Outline positions of truckmaster and assistant truckmasters. Explain where the truckmaster and assistant truckmasters ride.

Inspection of equipment preparatory to road exercises.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:
"Signals and Road Rules" No. V.

SECOND EXERCISE.

Trucks on road operating in sections.

Observe distances and speeds in open and closed formation.

Instruct in general road rules and enforce their observance.

Exercise thoroughly in use of signals.

Exercises in crossing bridges, placing of guards at crossroads, railroad tracks, etc.

Illustrate the handling of road repairs and disabled equipment.

Method of righting overturned truck by use of block and tackle.

Extracting truck from mud, etc.

On return to park, explain parking system and see that trucks are placed in position, properly spaced, and in line.

Exercise in knots to be used for towing, temporary repairs, etc.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:

"Signals and Road Rules" No. V; "General Principles of Convoy" No. III; "Knotting and Splicing" No. IX.

THIRD EXERCISE.

Trucks operating in company formation.

Exercise in maintaining proper speeds and intervals between sections in both open and closed formation.

Instruction in all signals and insist on uniformity and correct manner of giving signals as well as executing them.

Exercise in reversing convoy (caution against allowing rear wheels to leave firm, hard ground and illustrate what happens if they do).

Exercise in handling individual truck by hand signals. Do not allow verbal signals to be used during this exercise. Have trucks backed up to platform or an assumed place to unload.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:

"Signals and Road Rules" No. V.

FOURTH EXERCISE.

Trucks in company formation.

Night operations with and without lights in open and closed formation.

Exercise in whistle and verbal signals.

Caution men in halting trucks to avoid colliding with trucks ahead.

Explain use of white squares on back of trucks.

Insist on convoy moving slowly until drivers are confident of ability to handle trucks in dark.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:

"Signals and Road Rules" No. V.

FIFTH EXERCISE.

Trucks in company formation.

Field problem in map reading, including exercises in location, orientation, reading compass, calling attention to influence of large mass of metal on needle of compass.

Exercise in loading and unloading troops and materials.

In loading and unloading troops emphasize assistant driver's responsibility for men in getting them to the truck.

Exercise in maneuvering men into formation necessary for loading troops, following diagrams given in Manual.

Exercise in material loading, backing trucks to loading platforms, etc.

Distribution of loads with regard to weight.

Securing of loads.

Exercise in use of correct knots for securing loads.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lectures:

"Map Reading" No. VI; "Loading" No. VII; "Knotting and Splicing" No. IX.

SIXTH EXERCISE.

General review and field problem.

Furnish men with written orders and maps and allow them to execute instructions with as little assistance from instructor as necessary.

Explain and correct any mistakes made.

Give opportunity for all men to act in executive capacity.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:

"Convoy Problem" No. VIII.

SEVENTH EXERCISE.

Trucks in company formation in park.

Exercise in method of washing and cleaning equipment, also oiling and greasing.

Formation for formal inspection illustrating position of men and arrangement of equipment.

Formal inspection.

References: Tentative Manual of Instruction, M. T. C. R. O. T. C. Unit, Field Operations Lecture:

"Care of Equipment" No. IV.

MOTOR TRANSPORT CORPS
R. O. T. C. UNIT

ELEMENTARY AUTOMOTIVE ENGINEERING
LECTURES.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE I.

THE GASOLINE ENGINE.

(Instruction Charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Equipment: Dodge, White, Cadillac motors.)

The engine of a gasoline vehicle is the power plant, and while it could not operate without the aid of additional appliances such as the fuel system, the ignition system and cooling system, it is very important that it be thoroughly understood. First, as to principles; and, second, as to types.

The term "gas engine" is usually used to designate the internal combustion engine without regard to whether it operates with gas or liquid fuel. The purpose of all engines is to convert the *heat*, generated by the combustion of the fuel, into *work*. Existing engines may be divided into two classes according as the combustion takes place outside or inside the working cylinder.

In the first-named class, the heat of combustion is transmitted by conduction externally to a working medium which carries the heat into the cylinder and is there transformed into work. The most common example of this class is the steam engine; another example, though in limited uses, is the hot-air engine.

In the second class, the fuel is introduced into the cylinder in the form of an explosive mixture, and there is ignited; the heat generated by the combustion is transformed into work, acting directly on the piston—hence the name "internal combustion engine."

The term "cycle," as applied to an engine, may be defined as a series of events which are repeated in regular order, constituting the principle of operation. These several events comprise the transformations which take place in the working medium, or, with reference to the gas engine, the distribution and behavior of the fuel mixture in passing through the engine.

The gas engine derives its energy from the heat, generated by the combustion within the cylinder, of a mixture of fuel in the form of a gas, or spray, mixed with air in the proper proportion to form an explosive mixture.

The mixture is admitted to the engine intermittently, and the amount supplied at each admission is known as the charge. The combustion of each charge takes place under pressure attained by compression—a result of the inward movement of the piston after the charge is admitted and all valves closed.

The effect produced by igniting the mixture after compression is commonly called an explosion, which is simply a quick burning of the mixture. This sudden explosion causes a high degree of heat within the combustion chamber, resulting in considerable initial pressure, and gives to the piston an impulse, which decreases in intensity as the piston advances to make the power stroke, by reason of the expansion of the gases. The products of combustion are finally exhausted from the cylinder through the exhaust valves.

Expressed briefly, the working operation of a gas engine embraces: (1) the admission of the charge into the cylinder; (2) its compression; (3) ignition, combustion and expansion; and (4) the subsequent exhaust of the products of combustion.

In the operation of a gas engine, the number of strokes required to complete the cycle varies with the type of engine. For automobile propulsion, the cycle is usually extended through four strokes, although in a few instances it is completed in two strokes. Engines of these types are known as four-stroke-cycle, and two-stroke-cycle, respectively.

The four-stroke cycle or more commonly called the four-cycle engine, although more bulky than the two-cycle engine, and requiring, approximately, twice the number of cylinders for equal turning effect, is almost universally used for propulsion of automobiles; it has advantages over the two-cycle engine, which have more than offset its undesirable feature, and caused it to come into general favor. Among the advantages which may be mentioned are: efficiency, flexibility, adequate admission of charge at high speeds, higher degrees of expansion, and more efficient exhaust. There are four strokes comprising the working cycle of the four-cycle gas engine: (1) the intake, (2) compression, (3) power, and (4) exhaust strokes.

FOUR-STROKE-CYCLE ENGINE.

In defining the principles of four-cycle motor action, one can explain the matter very clearly by comparing the effect produced by exploding gasoline gas to that which obtains when one explodes gunpowder in a gun, for example in an old pattern muzzle-loading cannon. Considering the first phenomenon which obtains when gunpowder is burned, one can obtain some idea of how exploded gasoline vapor may be transformed into power. In fact, the preliminary operations which have been necessary before the gun was fired, are very similar to those which precede an explosion in the cylinder of the gasoline engine of the four-cycle type. Following first, the cycle of operations necessary to fire the cannon, it will be seen that a certain sequence is necessary. We have the loading, or charging of the gun. The powder which is carried in bags for convenience, is introduced in the muzzle and pushed back into the breech with the ramrod. After the powder has been compressed the ball is placed and tightly rammed in place on top of the powder in the explosion chamber. After the powder is properly compacted, it is exploded by means of a lighted fuse, or percussion cap, and the cannon ball is forced out through the open end because of the pressure of gas on its underside, this having been produced by the rapid burning of the powder.

The next operation is clearing the gun of the burned gases in order to introduce a fresh charge of powder and shot. The clearing is automatically performed. As soon as the ball leaves the mouth of the mortar the gas which is still under high pressure escapes to the atmosphere. After the bore is sponged out, one can introduce another charge and fire the cannon again. The power to propel the shot through the air has been obtained by burning a substance which before ignition had no power to produce motion of the ball. If an equal charge of gunpowder had been placed in the open air and the shot placed upon it, if the combustible material were ignited, there would be very little energy produced. There would be a flash of flame, but it is doubtful if this would have produced sufficient energy to cause the cannon ball to leave its position. Powder compacted in the cannon barrel produced useful energy because pressure was confined in a chamber having rigid walls at all sides, except one, this being the side of the cannon ball nearest the explosive. The metal surrounding the explosion chamber had sufficient strength to resist the high gas pressure, but the ball which was movable, was driven out because its weight was not sufficient to resist the force applied to it by the exploding powder.

The modern gasoline engine follows the action of the old-type muzzle loader. We can compare the action of the simple four-stroke engine with that of a cannon. The principal elements of a gas engine are not difficult to understand and their functions are easily defined. In place of the barrel of the gun, there is a smoothly machined cylinder with a small cylindrical, or barrel, shaped element fitting the bore closely which may be likened to a cannon ball. It differs in this important respect, however, that while the shot is discharged from the mouth of the cannon, the piston member sliding inside of the main cylinder can not leave it, as its movements back and forth from the open to the closed end and back again are limited by a simple mechanical connection, or linkage, comprised of crank and connection rod. It is by this means that the reciprocating movement of the piston is transformed into a rotary motion of the crank shaft.

During the suction stroke the piston moves outward and draws in a charge of the fuel mixture. The following inward stroke compresses the charge into the combustion chamber; at the end of this stroke the charge is ignited, causing a rapid rise of pressure, and subsequent expansion of the products of combustion during the next, or power stroke. The expanded gases are expelled from the cylinder during the return, or exhaust stroke of the piston.

The first and third are outward, and the second and fourth inward, that is, the piston moves away from the combustion chamber during admission and impulse, and approaches it during compression and exhaust, and the piston receives an impulse once in every two revolutions.

The action of the valves during the cycle is: During admission, the inlet valve remains open, and the exhaust valve closed; during the compression and power strokes, both valves remain closed; exhaust takes place with the inlet valve closed, and exhaust open, and the ignition takes place at a variable time, near the end of the compression stroke, depending upon the speed and load, so there will be

time for the pressure due to combustion to build up and thus secure a high initial pressure at the beginning of the power stroke. The heavy flywheel receives sufficient momentum during the power stroke to keep the engine going at approximately uniform speed during the period between impulses.

The weight and size of the flywheel must be considerable on account of the prolonged pauses between impulses; by reason also of the large-size piston necessary, there is considerable vibration. This is overcome by the use of several small cylinders, in place of a single one of large size, and this arrangement is called a multi-cylinder engine.

There are usually four or six cylinders in the medium and large sized vehicles; for those of small size there are sometimes only two, and in rare instances one. The action of a multi-cylinder engine in overcoming the objection to a single cylinder is that the heavy impulse of the single-cylinder engine may be divided into several small impulses by working a number of small pistons from one shaft. In order to reduce vibration and secure a better turning effect the cranks are so placed that the several impulses occur at different times. A small flywheel then suffices to secure approximately uniform rotation.

The efficiency of a gas engine is the proportion of heat turned into work as compared with the total heat produced by combustion. This does not represent the actual efficiency of an engine on account of various losses in operation which cause the actual or mechanical efficiency to be less than the thermal or theoretical efficiency as defined above.

With the cycle extended to four strokes, there is more time for admission and exhaust, and since these events take place at separable intervals, no chance is given for any of the charge to escape past the exhaust valve while open.

TWO-STROKE CYCLE ENGINE.

The two-cycle engine is used, to a limited extent, for automobiles; the essential difference between it and the four-cycle type is that the four operations of admission, compression, impulse, and exhaust, comprising the working cycle, are performed in one revolution instead of two. There is, then, one impulse for each revolution. From this, it follows that the weight is much less than that required for the four-cycle engine. The necessary mechanical features for two-cycle operations are as follows:

1. An inclosed crank case fitted with a valve arranged to open and admit fuel mixture at the front of the piston, on the inward stroke.
2. Inlet and exhaust ports so located that they will be uncovered during the outward stroke.
3. A by-pass tube connecting the interior of the cylinder with the crank case, so as to admit the charge at the proper point in the cycle.

During the first stroke the piston moves inward and draws in a charge of the explosive mixture into the enclosed crank case; during this operation the charge previously admitted to the cylinder is compressed and ignited as the piston nears the end of the stroke.

During the second stroke the pressure caused by the explosion of the charge drives the piston outward, and slightly compresses the

mixture drawn into the crank case during the previous stroke. Near the end of this stroke the piston uncovers the exhaust port and the burnt gases are exhausted. During the remainder of the stroke the piston uncovers the admission port, and the new charge, previously compressed in the crank case, is admitted to the cylinder, being deflected upward to the head end of the cylinder by a screen or "deflector plate" on the end of the piston. The "inrush" of the new charge helps materially to clear the cylinder of the burnt gases from the previous charge. The object of the deflector plate is to prevent the entering charge passing out through the exhaust with the burnt gases.

The two-cycle engine has the advantage over the four-cycle engine of less weight and the absence of poppet valves with their springs, stems, push rods, and cam shafts, thus effecting a more simple construction. Since the frequency of impulses is greater, a better turning effect is secured. The inefficiency of admission and exhaust of the two-cycle engine becomes more marked at high speeds. The four-cycle engine gives better fuel economy than the two-cycle engine.

NOMENCLATURE.

A gas engine is composed of stationary and working parts, i. e.: The stationary parts are: (1) The cylinder, and (2) crank case; the working parts are: (1) The piston, (2) connecting rod, (3) crank shaft, (4) fly wheel, and (5) valve mechanism.

THE CYLINDER.

The cylinder of a gas engine is open at the end toward the crank, and closed at the opposite end, save for inlet and exhaust ports, which are opened and closed by valves. The cylinder is supported by the crank case, made up of an intermediate piece to which the cylinder is attached and a lower piece which retains the oil.

COMBUSTION CHAMBER.

The combustion chamber corresponds to the clearance space in a steam engine, but its object is to provide a small space into which each charge of the fuel mixture may be compressed to considerable pressure, on the compression stroke of the piston, and then ignited. It is sometimes called clearance.

THE PISTON

The piston is a cylindrical box of proper size to slide back and forth in the cylinder bore and is of the type known as "trunk piston." The piston is single acting—that is, it is acted upon by power on the face only. To prevent leakage several grooves are cut in its circumference to receive packing rings, the type generally used being known as "snap rings."

The upper end of the connecting rod is pivoted to a "wrist pin," which is inserted in the piston through a hole bored through its central diameter. The wrist pin is retained in place by one or two set screws.

CONNECTING ROD.

The connecting rod transforms the to and fro motion of the piston into rotary motion and transmits the thrust or power impulse of the piston to the crank shaft. The connecting rod is usually of rectangular or I-shaped construction and has an adjustable bearing at each end. One end is pivoted to the piston by the wrist pin, and the other end to the crank shaft by the crank pin.

CRANK SHAFT.

The crank shaft is formed from a solid steel forging and consists of a central cylindrical piece, from which radiate one or more cranks, corresponding to the number of connecting rods.

FLYWHEEL.

On the end of the crank shaft is a heavy flywheel which receives sufficient momentum during the power stroke to keep the engine going at approximately uniform speed during the period between impulses, and assists in balancing the engine.

VALVE GEAR.

Each cylinder must have one inlet and one exhaust valve usually of the type which are called poppet or mushroom valves. These consist of metal disks beveled around one face, so as to fit into a counter-sink in the port and they are carried upon spindles. The stem or spindle is made of sufficient length to extend down into the crank case; it enters through a bushing, which serves as a guide. Attached to the end of the stem is a roller bearing, or follower, which rides on a cam, attached to the cam shaft, which is geared to the crank shaft in such proportion that it makes one revolution to every two of the crank shaft. By means of a spring the roller bearing, or follower, is held in contact with the cam. Valves may be operated from a single cam shaft when they are located on one side of the cylinder; when the valves are on opposite sides, two cam shafts are necessary.

PISTON RINGS.

Piston rings are made from a pipe-shaped casting, which is turned in a lathe to an outer diameter slightly larger than the cylinder. The inner circumference is then turned from another center, and the ring cut off and split at the thinnest section. Enough metal is removed at the split section so that the ring may be slightly compressed and again turned externally to the diameter of the cylinder while compressed. The latter operation causes the ring to bear evenly against the cylinder walls, thus making a tight joint. Although formed of a brittle substance, piston rings have considerable elasticity, being capable of opening sufficiently to slide over the outer diameter of the piston, and to "snap" back into the grooves.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE II.

TYPES OF MOTORS.

(Instruction Charts Nos. 4, 5, 6, 7. Equipment: Dodge, Cadillac, and Riker motors.)

The cylinder of a gasoline engine is made of cast iron or 20 per cent semisteel, and the water jackets are generally cast in one piece with it. The cylinders of an engine with more than one cylinder are either cast singly, in pairs, or en bloc.

The portion of the cylinder in which the piston moves should be a true circle and as smooth as possible. In the better grade of cars the cylinder walls are ground to a smooth finish so that there may be as little friction as possible. Any roughness of the walls will cause wear, which comes in the form of cuts and scratches lengthways, that permit the pressure to escape around the piston.

A motor is called either an "L," "T," or "valve-in-head" (the latter also I-head); this name is given according to the design of the cylinder block looking at the end.

The "T" head type of cylinder is made so that the exhaust valves are on one side and the inlet valves are on the other side. The "L" head type of cylinder is made so that the exhaust and inlet valves are all on one side of the cylinder. The valve-in-head cylinder has all the valves in the top of the cylinder.

In the "V" type engine of eight cylinders they are grouped in sets of four, which are placed 90 degrees apart, and on a twin-six cylinder engine the two sets of six are 60 degrees apart. Cylinders may be cast solid or with detachable head. The detachable head is gaining in favor. It permits easy access to the valves to remove carbon or to remove pistons, and is good manufacturing practice because it makes the grinding of the cylinders easier.

The following cars are made with detachable heads and are cast en bloc: Dodge, White, Standardized "B," G. M. C. Model 16, and Cadillac.

HORSE-POWER DETERMINATION.

A foot-pound is the amount of work expended in raising a weight of 1 pound 1 foot, or in overcoming a pressure of 1 pound through a distance of 1 foot.

Power is the rate at which work is done. It is the quotient of work divided by the time in which it is done, thus:

$$\text{Power} = \frac{\text{Work}}{\text{time}} \quad \text{or} \quad \frac{\text{pounds} \times \text{distance}}{\text{minutes}}.$$

One horsepower is 33,000 foot-pounds of work done in one minute. There are several factors on which the horsepower of a gas engine depends: (1) The mean effective pressure on the piston (in pounds per square inch), (2) the area of the piston (in square inches), (3) the stroke (in feet), and (4) the number of power strokes per minute. The product of these factors divided by 33,000 will give the indicated horsepower. This does not take into account the friction of the engine, which may amount to 10 per cent, or more.

Brake horsepower is the actual power delivered to the shaft, as determined by making a brake test. It is equivalent to the indicated horsepower less the power absorbed by the friction of the engine.

The pressure within a gas-engine cylinder during the suction stroke is about 1 pound less than the pressure of the atmosphere, on account of a certain degree of suction, or pressure reduction, necessary to overcome the frictional resistance encountered by the incoming charge as it flows through the inlet manifold and passages.

The velocity of the mixture flowing through the valves in a well-designed engine is from 4,000 to 5,000 feet per minute. The pressure of the atmosphere is about 14.7 pounds absolute, at sea level, that is, 14.7 pounds measured from the zero of a perfect vacuum. This is equal to zero pressure as measured on a steam gauge, which usually only measures pressures above the atmosphere.

The ignition occurs in the combustion chamber before the end of the compression stroke because combustion requires time; if the combustion begins at the proper instant before the completion of the compression stroke, the maximum pressure will be attained at the beginning of the power stroke. This is desirable (1) to avoid loss of power and (2) to insure sufficient reduction of the temperature of the gases at the opening of the exhaust valve to prevent injury to the latter.

At or near the beginning of the power stroke the maximum pressure of 350 pounds within the cylinder, due to combustion, is reached; the temperature at this point is excessive, being $2,000^{\circ}\text{F.}$, or even more. As the piston advances, the gases expand, and both pressure and temperature fall; near the end of the stroke, the exhaust valve opens and the pressure at this point drops almost to that of the atmosphere. This operation is possible with such high temperature as $2,000^{\circ}\text{F.}$, as the combustion chamber and cylinder are surrounded with a jacket through which cooling water circulates. This prevents the temperature of the cylinder walls and working parts rising beyond their proper limits.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE III.

TIMING AND BALANCING.

(Instruction Charts Nos. 2, 3, 4, 5, 6, 7, 8, 30, 32. Equipment: Dodge, Cadillac, and White motors:)

The system or process by means of which the moment of ignition and the opening and closing of the valves is regulated in an internal-combustion engine is called "timing." The timing of the valves is an expression analogous to "valve setting" in regard to a steam engine.

Balancing involves some mechanical means for rendering all movements perfectly even and for neutralizing thrusts and vibration; considerable ingenuity has been exercised in the effort to achieve a perfect solution. A single-cylinder engine is balanced by fastening counterweights on the opposite side of the crank, while in a two-cylinder engine the cranks are often placed opposite each other. This mechanically balances the engine, but the explosions will take place at irregular intervals and thus cause the engine to vibrate. In some engines both cranks are set the same way, and counterweights are attached as in a single-cylinder engine. The explosions in such engines take place at regular intervals, but in practice it is found that such engines vibrate more than the former kind or account of very poor mechanical balance.

It is not possible to perfectly balance an engine by counterweights: an engine may be balanced by counterweights to run at a certain speed with no perceptible vibration, but a variation below or above this speed will throw it out of balance. The arrangement of the cranks of a multicylinder engine produces a mechanical balancing effect in itself, but in order to reduce the vibration to a minimum, timing of the explosions in the various cylinders is necessary.

The timing of the valves is effected by arranging the cams which operate the valves so that successive firing cylinders are on opposing cranks. Manufacturers ordinarily express the rotation of firing as the engine fires 1, 2, 4, 3, or it fires cylinder 1, then 3, then 4, and then 2. The adjustment of the ignition mechanism must follow the same rotation as governed by the cam rotation, in order to govern the firing so far as balance is concerned. In ascertaining the method of the timing, as regards the firing of the successive cylinders, the engine should be turned over slowly by hand. By watching the lifting of the inlet or exhaust valve stems, the point of ignition will come about one-half turn after the seating of the inlet valve on each cylinder. The timing device governs the ignition. To adjust the timer the engine should be turned slowly until the inlet valve of

cylinder No. 1 seats. It is then given an additional half turn; if the timer be fastened to the cam shaft by a set screw, the latter may be loosened and turned around until contact is made with one of the points and the set screw tightened. The wire leading to spark coil No. 1 is connected to this terminal and the secondary wire of this coil to spark plug on cylinder No. 1. The engine is now slowly given another half turn, during which it should be noted which inlet valve seats; it should be that of cylinder No. 2 or No. 3. The primary wire of the second spark coil is connected to the binding screw of the timer point now in contact, and the secondary wire of this coil to the cylinder which has been found to be in action. The remaining cylinders are then connected up by similar procedure.

The dead center of an engine may be determined as follows: At some easily accessible place near the rim of the flywheel a pointer is fastened to the frame of the engine. At the top of each cylinder there is usually a plug or pet cock which should now be removed. Next, having procured a smooth stick of wood, or a thin iron rod which will fit loosely through the hole in the top of the cylinder, it is inserted into the cylinder so that it rests upon the piston. The stick should be kept vertical. The engine is turned until the stick appears to be in the highest position, and a mark made on the stick with a pencil at the edge of the hole. Another pencil mark is made about $\frac{3}{4}$ or 1 inch from the first mark. Now the engine is turned until the second mark corresponds with the edge of the hole, and a mark is made on the flywheel corresponding with the pointer which has been fastened to the frame. The engine is turned over, past the bottom center, until the same mark again registers with the edge of the hole; at this point a mark is made on the flywheel corresponding to the position of the pointer. With a pair of dividers, or a flexible rule, the distance between these marks is bisected and marked. This latter mark is turned to the pointer, and cylinder No. 1 is on its exact top center.

The other centers may be found from the first obtained mark on the flywheel thus: In a four-cylinder engine No. 4 would have the same mark as No. 1. For No. 2 and No. 3 another mark will have to be placed directly opposite the one of No. 1 and No. 4. In a six-cylinder engine, one of the remaining cylinders would have a mark corresponding with the first, while a mark for each pair of the other cylinders would have to be placed at 120° from the first mark, commonly spoken of as "placing them on thirds."

The magneto itself has to be "in step" with the engine. In the timing of a high or of a low tension magneto there are certain points in the revolution of a magneto when the intensity of the spark is greatest; this should be taken advantage of, whether it be a high or low tension magneto.

If the engine has been equipped with a magneto, the drive gears are marked on their rims so that with the marks on the different gears corresponding with each other, the magneto is in step with the engine. In such a case, if the gears have been shifted, it is a simple matter to replace them. If, however, no marks be present, the wires are connected to the terminals, and one of the valve chambers opened so that the spark can be seen. The engine is now rapidly turned over by hand, and the spark noted. Marks are made on the gears with a

pencil, so this position can be found again if necessary. The idler gear is now shifted a couple of teeth, and this position indicated with a different mark: the engine is turned again and the spark noted. This process is repeated, shifting the gears a couple of teeth each time. The mark corresponding with the best spark should be selected and a permanent mark put on the gears.

It is important, when attaching a magneto to an engine, that the drive and driven gears be keyed to their shafts, after the right position has been found. When the magneto has been timed to give the best spark at the top center, and the spark lever advanced, the spark would not be as intense if the speed of the engine remained constant, but as the spark is advanced for high speeds only, the increased speed of the magneto will more than make up the deficiency and produce an even better spark. As there are two dead points during each revolution of the magneto, it should be geared so that none of the dead points correspond with the sparking periods.

When equipped with a multiple-unit coil and timer, the same rules as applied to a battery equipment will be applicable, and the magneto may be timed the same way, by turning and testing the spark. The spark plugs may be taken out and laid on the cylinder, with the cables connected, thus making the spark visible. When a distributor is used, it must be timed so that the rotor contact registers with one of the terminals for the spark cables for each cylinder before the spark is to take place. The contacts must follow the regular firing order of the cylinders. If the magneto be equipped with a self-contained coil the same rule holds true, the only difference is in the wiring.

When a high-tension magneto is timed, the cables must be connected to the spark plugs in the regular firing order of the cylinders to determine the order of sparking the plugs. They may be laid on the cylinder heads while the magneto is being turned over. The gears must be shifted one tooth at a time until the spark takes place at the right time, which is about the top center when retarded.

The speed of a magneto is determined by the number of cylinders, as well as the cycle of the engine. Since there must be four explosions for each two revolutions of a four-cylinder engine and as each revolution of the armature produces two sparks, there must be one revolution of the armature for each revolution of the engine.

Before starting to time an engine, it is important to examine the valve gearing to ascertain whether the valves open and close at the proper time. If the valves be out of "time," first examine the valve stems and push rods for lost motion, which should be no more than the thickness of heavy paper. When the valves open and close late as compared to the movement of the piston, the valve is said to be late. If all of the valves be operated by the same cam shaft, the valves are bound to be "in step" with each other, providing there is no excessive lost motion, but if one of the valves be early, or late, it is evident that they are all out of time. If the exhaust and inlet valves be operated by separate cam shafts, it may happen that both sets of valves may be out of time with each other, at the same time being out of time with the piston, or one set may be in time with the pistons, while the other set is out of time. The valves may all be considerably out of time, and the engine will still run, but at the expense of reduced power,

increased fuel consumption, and excessive vibration. Improper timing is detected by unsteady action, especially at the higher speeds.

On some engines the cams are made independent of the cam shaft, and are keyed to the latter, hence, it is possible that, in overhauling the engine, some of the cams may have been replaced wrongly. Although the cams can not be shifted out of time with each other, it is possible that the surface of some may be worn more than others, or on such engines where the cams act upon rollers carried by the end of the push rod, or by a carrier, the roller and the pin may be worn to such an extent as to make proper timing impossible without removal of the worn parts. This lost motion can not be taken care of when adjusting the lost motion between valve stems and push rods; only the lost motion in the direction of the valve travel can be adjusted. The lost motion in the rollers, the carrier suspension, or the push-rod bushings acts in a direction at right angles to the valve travel and affects the timing. The main objection to lost motion in the gear teeth would be the noise. When the cams raise the valves against the spring action, the tension upon the teeth is upon their driving faces, while when the valves seat again by the spring action, the tension upon the teeth is on the reverse side, causing the gear teeth to clatter back and forth several times during each revolution.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE IV.

IGNITION.

(Instruction Charts Nos. 1, 5, 30, 31, 32, 33, 34, 35, 36, 37, 38. Equipment: Dodge, Cadillac, Class "B," White.)

It is of prime importance that the automobilist acquire a thorough knowledge of ignition. Many of the troubles still encountered, notwithstanding numerous improvements, have arisen from failure of the ignition system to perform its proper function. The engine may operate with an imperfect fuel mixture if the ignition system be in working order, but any defect in the latter will, in nearly every case, cause the engine to misfire, or stop.

The name electricity is applied to an invisible agent, known only by its effects, and the various ways in which it manifests itself. Copper, as it offers little resistance to the flow of the electric current, is generally used for conductors. The current must have pressure to overcome the resistance of the conductor.

The pressure under which the current flows is measured in volts, and the quantity that passes, in amperes. The resistance with which the current meets in flowing along the conductor is measured in ohms. The flow depends upon the pressure and the resistance. The flow of the current is proportional to the voltage and inversely proportional to the resistance. The latter depends upon the material, length, and diameter of the conductor. The current always flows along the path of least resistance and there should be little or no leakage. This is accomplished by insulating the wires, that is, covering them by wrapping them with cotton or silk thread, or other insulating materials.

A defect in the insulation which allows the current to leak and return to the source without doing its work, is a short circuit. The conductor which receives the current from the source is called the lead, and the one by which it flows back, the return. When wires are used for both lead and return, it is called a metallic circuit; when the metal of the engine is used for the return, it is called a ground circuit. This term originated in telegraphy, where the earth is used for the return. In ignition diagrams then, the expression "to ground" means to connect the point with the metal of the engine.

Whenever the current is checked by a resistance, the energy of its flow is converted into heat, which makes electricity available for ignition. This is accomplished in two ways, (1) by suddenly breaking a circuit, and (2) by placing in the circuit a permanent air gap which the current must jump. In either case, the intense heat caused

by the enormous resistance interposed, instantly produces a spark, which ignites the charge. In these two methods of producing the spark, the first is known as the make and break, or low tension, and the second, the jump spark, or high tension.

An electric current is said to be (1) direct, when its direction is continuous, (2) alternating, when it flows rapidly to and fro in opposite directions, (3) primary, when it comes directly from the source, (4) secondary, when the voltage and amperage of a primary current have been changed by a transformer or induction coil, and (5) low tension, or high tension, according as the voltage is low or high.

High and low tension currents vary: i. e.—a high tension current is capable of forcing its way against considerable resistance, whereas, a low tension current must have its path made easy. A continuous metal path is an easy one, but an interruption in the metal, as the permanent air gap of a spark plug is difficult to jump. Air is such a poor conductor that it is usually spoken of as a nonconductor. The latter term should not be encouraged, as, strictly speaking, there are no nonconductors; the word insulator is to be preferred.

The low tension current is only able to produce a spark when parts are provided in the path, and so arranged that they may be in contact and then suddenly separated. The low tension current will, as the separation occurs, tear off very small metallic particles and use these as a bridge to keep the path complete. Such a bridge is called an arc, the heat of which is used for ignition.

The poles of a magnet are the two regions in which the magnetic property is strongest. In a bar-shaped magnet the poles are at the ends: half-way between the poles there is no attraction at all. In a bar magnet, that end which tends to point toward the north is called the north or positive pole, and the other the south or negative pole. When a current of electricity passes through a wire, what is known as a magnetic field is produced. A magnet may be produced by passing an electric current through an insulated wire conductor coiled around a core of soft iron. This is called an electric magnet. If the bar be of soft iron, it will be very strongly magnetized, but will not retain its magnetism for any length of time after the current ceases to flow: if of steel it will not be magnetized so strongly nor so quickly, but will retain its magnetism for a great length of time after the current is shut off. In winding wire around a bar, it should be wound continuously in one direction, as the polarity, or location of the poles of the bar, depends upon the way the current flows through the wire. The poles may be identified by holding a permanent magnet or a compass needle near one pole of the electromagnet: the north pole of one will attract the south pole of the other, and vice versa.

If the coil of an electromagnet be surrounded by a second coil of insulated wire an induced current is produced in this second coil by what is known as induction, each time the current in the inside coil begins or ceases flowing. The inside coil is called the primary winding, and the outside coil the secondary winding. Similarly, the current passing through the inside coil is called the primary current, and that in the outside coil, the secondary or induced current.

By varying the relative number of turns in the two coils the tension or voltage of the two currents is changed proportionately. That is, if the primary winding be composed of ten turns and the secondary of one hundred, the voltage of the secondary current is increased approximately ten times that of the primary. This principle is employed to produce the extremely high tension current necessary with the jump-spark method of ignition.

An electric current may be produced by (1) chemical, and (2) mechanical means. In producing electricity by chemical action, two dissimilar metals, such as copper and zinc, called electrodes, are immersed in an exciting fluid. When the electrodes are connected at their terminals by a wire or conductor, a chemical action takes place, producing a current which flows from the copper to the zinc. That terminal from which the current flows is called a plus or positive pole, and the other electrode terminal a minus or negative pole.

This device is called a cell, and the combination of two or more connected so as to form a unit, is known as a battery. The word "battery" is frequently used incorrectly for a single cell. It requires more than one cell to form a battery. Cells are classified primary or secondary, according as they generate a current of themselves or require to be charged from an external source before yielding a current. In the latter type energy is stored by chemical action which is afterwards yielded as current flowing in the opposite direction to that of the charging current. An electric current can also be produced by mechanical means.

A dynamo has an electromagnet, known as a field magnet, which produces a magnetic field, and a coil of wire or armature which, when revolved in the magnetic field, develops electric current. A magneto has (1) a permanent magnet to produce the magnetic field, and (2) an armature which is usually arranged to revolve between the poles of the magnet. The basic principles upon which dynamos and magnetos operate are the same. Magnetos are divided into two classes: (1) low tension, and (2) high tension, according as they generate a current of low or high voltage. Low tension magnetos are used for make and break ignition, and the high tension type for the jump-spark system. A low tension magneto in combination with a secondary induction coil may be used to produce a high-tension spark.

To obtain a spark in high-tension ignition, a spark plug is used which consists of two stationary electrodes, one of which is grounded to the engine cylinder and the other insulated. The points of the electrodes are permanently separated from each other by about $\frac{1}{32}$ of an inch, the space between the points being known as an air gap. This space offers so much resistance to the flow of the electric current that a very high pressure is required to cause the current to burst through the air gap and produce a spark, hence the term "high-tension ignition." Since the spark jumps from one electrode to the other, this method of igniting the charge is also known as the jump-spark system. The spark itself is properly described by the prefix, high tension or secondary.

In the production of the high-tension spark, two distinct circuits are necessary: a low tension or primary circuit, and a high tension or secondary circuit. The current which flows through the low-tension

circuit is called the primary current, and that which it induces in the high-tension circuit, the secondary current.

The high voltage necessary to produce a secondary spark is obtained by a device known as a secondary induction coil, which transforms the primary current of low voltage and high amperage into a secondary current of high voltage and low amperage, that is, the volume of the current is decreased and its pressure increased.

The general principles upon which high-tension or jump-spark ignition is based is as follows: An automatic device is placed in the primary circuit, which closes and opens it at the time a spark is required. When the circuit is closed, the primary current flows through the primary winding of the coil and causes a secondary current to be induced in the secondary winding. A spark plug being included in the secondary circuit opposes the flow of the current by the high resistance of its air gap. Since the pressure of the secondary current is sufficient to overcome this resistance, it flows or "jumps" across the gap, and in so doing intense heat is produced, resulting in a spark.

Sometimes the spark is obtained by keeping the primary circuit closed except during the brief interval necessary for the passage of the spark at the plug points. A secondary spark then may be produced by either open or closed circuit working, that is, the primary circuit may be kept either open or closed during the intervals between sparks.

A contact maker is that which momentarily closes and breaks the circuit at the time of the spark. A contact breaker is that which keeps the circuit closed except at the time of the spark. A contact breaker is used to advantage on small engines run at very high speed, as it allows time for the magnetism or magnetic flux in the core of the coil to attain a density sufficient to produce a good spark.

A timer is a device which controls the primary current only. A distributor is a timing device which controls both the primary and secondary currents, and an interrupter is a contact breaker on a magneto which breaks the primary circuit at the time a spark is required.

The current from a nonsynchronous alternating current magneto produces very little wear on the vibrator points because the current, in the aggregate, is in each direction for one-half the time. The wear on vibrator points may be reduced when a battery is used by periodically changing the direction of the flow of the current. This is done by reversing the wires attached to the battery terminals.

Some advantages of ignition with high-tension magnetos are that the wiring is greatly simplified since the coil and condenser are a part of the magneto. Also, hand advance of the spark is not required. The hand advance is not necessary, owing to the intensity of a magneto current increasing with the speed. Hence, when running slowly, the spark produced in the cylinder will be weak and the charge will be ignited slowly. At high speeds, the strength of the current being greater causes the charge to ignite more rapidly; this charge produces an effect equivalent to advancing the spark.

When starting an engine on a magneto the crank must be turned faster than when a battery is used, because the armature must be turned at a certain speed to generate the required current. Ordinary spark plugs are not well adapted to a magneto, because the current

being stronger than that furnished by a battery, the greater heat of the current tends to burn the slender points. Therefore, with a magneto they must be larger for satisfactory working. The gap of a magneto plug should be less than that of an ordinary plug, because the current, while of greater amperage and heating value, is of less voltage than with a battery system. The gap should not be more than one sixty-fourth of an inch. It is important that the revolving switch, which distributes the secondary current, and the contact breaker should be kept clean.

Dual ignition is one with two modes of ignition having one or more parts in common, and double ignition is two independent means of ignition having no parts in common; thus, if anything should happen to one system the other may be brought into use.

To successfully cope with ignition troubles there are two requisites: (1) A thorough knowledge of the system used, and (2) a well ordered course of procedure in looking for the cause of the trouble. In many ignition systems the chief difficulty encountered in the location of defects arises from the fact that faults in different parts of the circuit sometimes make themselves manifest by the same symptoms. If each defect had its individual symptom, locating the trouble would be comparatively easy; but, as it is, it is sometimes quite difficult to find the defective parts. In general, the following method should be adopted to locate ignition troubles:

(1) The source of current supply should be examined: if a battery, each cell should be tested separately, and any one found to be weak removed. If a magneto be used, it should be disconnected and the armature turned by hand: in case the field magnets have not lost their proper strength the armature should turn perceptibly hard during certain portions of each revolution.

(2) The primary circuit should be examined for breaks: all connections made bright and secured firmly by the binding screws, and the timer contacts cleaned.

(3) The spark-plug points should be cleaned and the air gap made the proper length—about one thirty-second of an inch.

(4) The vibrator contacts should be made flat and clean, and the vibrator properly adjusted.

In testing the spark plug it should be unscrewed and placed on the cylinder without disconnecting the wire to the insulated electrode: the body of the plug only should touch the metal of the cylinder. On cranking the engine the spark should be "fat" if everything be in good condition: if a weak spark be produced it may be due to either a loose terminal, run-down battery, or badly adjusted vibrator. When no spark can be obtained the entire system must be examined and tested, beginning at the battery.

Plug testing in multi-cylinder engines.—After starting the engine all plug wires are grounded except one, thus running the engine on one cylinder. In case there be no misfiring after testing at various engine speeds, it can be taken for granted that the plug is sound. The remaining plugs are tested in the same manner. When a multi-unit coil is used, a faulty plug may be located by holding down all the vibrator blades but one, so that only one spark plug operates. Running each cylinder separately by this means it can easily be

ascertained which plug is defective. Some coils are provided with little knobs for cutting out cylinders in the manner just described.

Complete break in the wiring.—The engine is placed upon the sparking point, the primary switch closed, and the two terminals of the suspected wire touched with a test wire. A flow of current indicates a break.

Partial break in the wiring.—A partial break or one held together by the insulation may sometimes be located by bending the wire sharply at successive points along its length, the engine being at the sparking point and the switch closed as before.

Primary short circuits.—The primary wires should be disconnected from the coil, leaving the ends out of contact with anything. There is a short circuit if, on touching the switch points momentarily, a spark appear. A short circuit may sometimes be overcome by clearing all wires of contact with metallic bodies, and pulling each wire away from the others which were formerly in contact with it.

Secondary short circuits.—The secondary lead from the spark plug should be disconnected. Under this condition the high tension current may sometimes be heard or seen discharging from the secondary wire to some metallic portion of the car. Water in contact with the secondary wire will sometimes cause a short circuit unless the insulation be of the best quality.

The primary switch.—This portion of the primary circuit sometimes causes trouble by making poor contact. This is generally due to the deterioration of the spring portion of the metal, which gradually loses its resiliency. Snap switches sometimes fail through the weakening of the springs which hold them in the "on" or "off" position. The contacts of a switch should be kept in good condition.

Primary connections.—All binding posts and their connections should be clean and bright. The wires should be firmly secured to the binding posts, as a loose connection in the primary circuit is often the cause of irregular misfiring or the stopping of the engine.

Vibration.—Since the wires are subject to constant vibration, a number of strands of fine wire is better than a single heavy wire, as the latter is liable to be broken. In securing the wire to the binding post, care should be taken that all the strands are bound.

Timers.—These may give trouble by (1) presence of dirt, (2) loose contacts, or (3) division of the spark; this latter effect is sometimes caused by metallic particles wearing off the revolving part forming a path so that the spark passes from the revolving part to more than one contact.

Coils.—The part of a coil which requires most frequent attention is the vibrator. The contact points are subject to deterioration on account of the small spark always present between the points when the coil is in operation. In time, the points become corroded and burned, and therefore require to be resurfaced by smoothing with a fine file. A faulty connection to the condenser is at once shown by large sparks at the vibrator points. Any repairs to a coil, aside from the vibrator, should always be done by an expert, as the construction is very delicate.

Spark plugs.—Repeated failure to start when the coil vibrator operates, indicates a faulty spark plug. A rich gasoline mixture often leaves a carbon deposit, which, being a partial conductor, short

circuits the plug. The porcelain insulation, on account of its brittleness, may crack inside the sleeve, allowing a spark to pass there instead of at the gap. Mica insulations sometimes become saturated with oil, causing the layers to separate, permitting a short circuit.

Engine misfires and finally stops.—This may be due to the exhaustion of the battery, and is indicated by a weak spark and very faint vibrator action.

Engine suddenly stops.—This is generally caused by a broken wire or loose switch which does not stay closed. In the case of a single cylinder, the broken wire may be either in the primary or secondary circuit; if a multi-cylinder engine, the break is in the primary circuit.

Engine does not start.—Usually caused by (1) primary switch not closed, (2) battery weak or exhausted, (3) entire or partial break in wire, (4) loose terminal, (5) moisture on spark plug, (6) fouled plug, (7) spark too far retarded or advanced, or (8) too slow cranking with magneto ignition.

Engine runs fitfully.—Frequently results from a partial break in the wiring, especially in the primary circuit.

Precignition.—Caused by (1) some small particle in the cylinder becoming heated to incandescence, (2) the electrodes of the spark plug becoming red hot, or (3) intermittent short circuit in the primary.

Engine runs with switch open.—Usually caused by (1) overheated engine or plug points, (2) primary short circuit, (3) defective switch, or (4) an incandescent particle inside the cylinder.

Engine misfires.—This may be caused by (1) weak battery, (2) partial break in conductor, (3) loose or disconnected terminal, (4) intermittent short circuit in the secondary, (5) faulty action of either timer or vibrator contacts, (6) bent vibrator blade, (7) faulty spark plug, or (8) air gap too large.

Knocking of engine.—Too advanced a spark sometimes produces this effect.

Knocking in the cylinder.—The form of unusual noise commonly described as "knocking" consists of a regular and continuous tapping in the cylinder, which is so unlike any sound usual and normal to operation, that, once heard, it can not be mistaken. Too much advance of the spark sometimes produces this result.

Loss of power without misfires.—This may be due to badly adjusted coil contacts, poor spark, or incorrect timing.

Explosions in the muffler.—These are usually caused by misfiring, partially charged storage battery, or by one cylinder not working.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE V.

FUEL SYSTEMS.

(Instruction Charts Nos. 1, 5, 13, 14, 15, 16, 17, 18, 19, 28. Equipment: Dodge, White, Cadillac U. S. A. Standard, Rayfield, Stromberg, Ball & Ball, Zenith, Marvel, and Stewart carburetors.)

While it is apparent that the chief function of a carbureting device is to mix hydrocarbon vapors with air to secure mixtures that will burn, there are a number of factors which must be considered before describing the principles of vaporizing devices. Almost any device which permits a current of air to pass over or through volatile liquid will produce a gas which will explode when compressed and ignited in the motor cylinder. Modern carburetors are not only called upon to supply certain quantities of gas, but these must deliver a mixture to the cylinders that is accurately proportioned and which will be of proper composition at all engine speeds.

Flexible control of the engine is sought by varying the engine speed by regulating the supply of gas to the cylinders. The power plant should run from its lowest to its highest speed without any irregularity in torque, i. e., the acceleration should be gradual rather than spasmodic. As the degree of compression will vary in value with the amount of throttle opening, the conditions necessary to obtain maximum power differ with varying engine speeds. When the throttle is barely opened the engine speed is low, and the mixture must be richer in fuel than when the throttle is wide open and the engine speed is high.

When an engine is turning over slowly the compression has low value and the conditions are not so favorable to rapid combustion as when the compression is high. At high engine speed the gas velocity through the intake piping is higher than at low speed, and regular engine action is not so apt to be disturbed by condensation of liquid fuel in the manifold due to excessively rich mixture or superabundance of liquid in the stream of carburefed air.

The duties of a carburetor are to so control the supply of air and gasoline that the resulting mixture will always contain the two ingredients in the proper proportions. There must not be too much gasoline vapor, as fuel would be wasted either by being decomposed into soot, or unburned, on account of insufficient supply of air to consume it. Again, too much air, though the mixture should ignite, would lower the temperature of combustion and thus diminish the expansion.

The two most important types of the carburetors are the "sprayer" and the "surface" carburetors. In the operation of the sprayer carburetor, the fuel is atomized through a minute nozzle and mixed with a passing air current. The action of a surface carburetor consists in passing air over the surface of a small "puddle" of the fuel. The sprayer is the prevailing type. For this purpose the essential features necessary to produce a proper fuel mixture are shown in the instruction chart. (See Instruction Chart No. 13.) The drawing illustrates a receiving chamber and mixing chamber, the two being connected by a small passageway or duct which terminates at the sprayer, made adjustable by the needle valve. The lower end of the mixing chamber is open to the atmosphere, while the upper end is provided with auxiliary air ports having a collar, or sleeve, with which to adjust the opening of the ports to the atmosphere.

In explaining the action of this rudimentary carburetor it is assumed that the receiving chamber is filled with gasoline to a level, very near the elevation of the spray nozzle, and that the supply is replenished as it is used so that the fluid level is kept consistent. The upper end of the mixing chamber of the carburetor is connected to the engine beyond the throttle, as shown in chart. On each suction stroke the piston motion causes a partial vacuum in the mixing chamber; the intensity of the vacuum depending upon the speed.

Assuming the engine to be working at slow speed with a heavy load, and the auxiliary ports closed by the sleeve, the gasoline supply may be adjusted by the needle valve so that the engine will receive the proper proportion of gasoline vapor and air from the carburetor. The air supply entering at the bottom of the carburetor is the primary air. The air supply entering through the auxiliary ports is the secondary air. If part of the load on the engine be removed so that it will run, say, twice as fast, the amount of air and gasoline delivered for each charge will not be the same, for under these conditions the mixture will become too rich; that is, too much gasoline will be fed for the amount of air passing through the inlet at the lower end of the mixing chamber. This is caused by an excess of gasoline, and is due to the fact that, in order to get twice the amount of air through the inlet, the suction has to be more than doubled to compensate for the increased frictional resistance set up by the higher velocity of the air passing through the inlet. The suction, or degree of vacuum in the carburetor being more than doubled, will induce a flow of more than twice the amount of gasoline. The velocity of the air increasing in passing through the inlet is due to the expansion of the air in entering the carburetor, resulting in an increase of velocity more than twofold after expansion. This suction may be restored to its normal condition so that the mixture will not become too rich by slightly raising the sleeve so as to partially open the air ports. This allows some air to enter through the auxiliary air ports, thus reducing the velocity of the entering air and relieving somewhat the suction at the lower inlet. The amount of opening of the auxiliary air ports necessary for any change of engine speed is found by experiment.

The engine speed may be maintained constant under varying load if a throttle valve be placed in the passage between the auxiliary ports of the carburetor, the load may be altered without any variation in the engine speed, by adjusting the throttle opening.

The modern carburetor differs from the rudimentary or primitive device shown in chart. In actual construction automatic devices are employed to maintain the gasoline in the receiving chamber at constant level and to adjust the auxiliary port openings to different engine speeds.

The term float chamber is used instead of receiving chamber, since a float is almost always used to regulate the flow of gasoline into the chamber, and is an automatic device to maintain the gasoline supply in the float chamber at the same elevation as that of the spray nozzle. This is necessary because an initial suction is required to lift the gasoline to the mouth of the nozzle before spraying can begin. The slightest suction only is required to draw air through the primary air inlet; there is, however, a certain minimum suction below which no gasoline can be fed, depending on the difference in the level of the supply and the level of the spray nozzle. This level is maintained by a "float feed" device which consists of a cork or hollow metal float placed in the float chamber. It is connected so as to operate the gasoline inlet valve, usually by means of levers. These are arranged in such a manner that as the gasoline enters the float chamber through the inlet valve the float rises, and in so doing closes the valve, thus shutting off the supply when the gasoline reaches the desired level.

A simple float feed construction is shown in the chart. The float is constructed concentric with the inlet valve; that is, it is placed around the same center. In the bottom of the float chamber is a small tube through which the gasoline must flow to the spray nozzle. One object of this tube is to prevent small particles of dirt and bubbles of water that may be in the gasoline from directly entering the spray nozzle. The plug at the bottom of the float chamber has a wire screen to catch any foreign matter that may be in the gasoline, in order that it may not lodge in the spray nozzle and impede the flow of the liquid.

There should be means of adjusting the height of the float to suit different grades of gasoline, as the level of the float depends upon the specific gravity of the liquid. Counterweights are employed and this construction is desirable owing to the facility with which the fuel level can be adjusted. To this end the counterweight is either increased or diminished. In order to obtain uniform results, especially where a car is operated on hilly roads, the float chamber with its float should be constructed concentric with the spray nozzle, so that any inclination of the car, in ascending or descending a hill, will not disturb the gasoline level with reference to the nozzle.

Floats are usually made of cork or sheet metal. Cork floats are liable to become saturated with gasoline, thus losing their buoyancy. Metal floats sometimes leak. A float should be without working joints, and particularly without frictional contacts with levers. A float chamber should be constructed to open at the bottom. This facilitates removal of any water, ice or dirt, and removal of the float itself, without opening the top and permitting dirt to fall in from above. The float and removable bottom can be replaced with a stream of gasoline flowing upon them, which will wash away particles of dirt, if any accidentally get on the parts while being replaced. With a top opening, ice in the bottom of the chamber may not only support the float and prevent it acting to admit gasoline,

but may also bind the float so firmly that it can not be removed to permit removal of ice, which may prove an unpleasant predicament if away from means of warming the carburetor.

The fuel flow should enter from a single direction, either up or down, so that no pockets exist in which water or dirt may gather. The inlet needle valve may be kept tight and in perfect working order by occasional grinding. To facilitate this, the construction of the carburetor should be such that the valve is easily accessible. A feature which tends to keep the inlet valve in good condition is that the motion of the car tends to move the valve to some degree, even though slight, which movement serves to force away any particles of dirt that may lodge on the point during the passage of the liquid. On this account, it is best if the float and valve be fixed one to the other, so that the point partakes of the motion of the float and liquid in the chamber. The float chamber must be provided with an air vent to prevent the accumulation of any excess pressure which would interfere with the proper flow of the gasoline.

A float pin or "tickler" is a device for depressing the float to obtain an excess of gasoline when such is required for starting the engine. A rich mixture may be obtained in starting, without tickling the carburetor, by throttling the primary air supply. Some motorists regard it as a necessary preliminary in starting to "tickle" the carburetor, but carburetors differ; with some it is necessary that the level in the float feed chamber be high, in others not so high. Some carburetors flood easily, while others never flood.

It is as difficult to start on an over rich mixture as it is with a lean one. Any small tickling of the carburetor serves to start the nozzle and create a small amount of mixture. But this process soon floods the carburetor, and as the quantity of air supplied is small and can not be increased to any extent before the motor starts, flooding is apt to fill the inlet manifold with almost pure gasoline vapor and the motor will not start.

Many motors will start without touching the carburetor, and in the case of others the process of starting is rendered far easier by the moderate application of attention of this sort. In priming a carburetor the float pin should be depressed and held down for a few seconds. This will cause as much, if not more, gasoline to enter in a given space of time than if the pin be worked like a pump. The latter operation as frequently performed is liable to injure the float.

The float pin is usually arranged to pass down to the float through the air vent tube. Since gasoline has considerable weight, and consequent inertia, the passage to the nozzle should be both short and large. If the passage be short, the liquid will respond more readily to the suction; if large, the friction will be less on account of the reduced velocity of flow. With a long passage, the effect of inertia is more marked, causing the liquid to respond less quickly to the suction, the strength of which changes during each intake stroke. On account also of this inertia effect, the liquid does not get started until a considerable volume of air has passed the nozzle, making the early part of the charge too lean. Now, as the suction decreases, the inertia of the liquid causes it to continue to flow making the latter portion of the charge too rich, and probably leaving between

charges unsprayed drops of liquid, which either fall on the walls of the carburetor or are drawn into the engine.

The spraying effect in the simple form nozzle is less marked than that obtained with nozzles having a number of slots. However, with the single nozzle, there is less danger of it becoming clogged. The operation of a multi-slot nozzle is undoubtedly better than one with a single opening, but it is necessary for the construction to be such that it may be readily withdrawn to clean the small spray slots.

The amount of liquid passing through the nozzle may be varied by an adjustable needle or metal rod having a conical point. The needle valve, which regulates the supply of fuel at the nozzle, should have suitable connections so that it may be adjusted by the operator, and enable him, while operating the car, to vary the proportion of the mixture, and thus secure the greatest power by trial, as well as to accommodate the device to the temperature and humidity of different days, and also to the gravity of different grades of fuel.

Some carburetors are fitted with two or more simple nozzles, the idea being that the several nozzles forming the unit, by coming into action progressively as the power demand increases, will produce the same effect as though several separate carburetors were used, each in turn being brought into action.

The small inclosure or passageway containing the spray nozzle is called the mixing chamber. The mixing chamber, as its name implies, is the place where gasoline and air are brought together in proper proportion and mixed to form the fuel charge for the engine. It is provided with a main air inlet and auxiliary ports as before described, but the latter are arranged to operate automatically. The outlet to the engine is fitted with a throttle valve, permitting the quantity of the mixture to be varied.

The construction of the mixing chamber with its appendages follows substantially the arrangement shown in the chart. This illustrates a mixing chamber with the spray nozzle located in the center. The adjustable needle valve regulates the flow of gasoline to the nozzle. The mixing chamber is open to the atmosphere at its lower end, through which the primary or main air supply enters. A secondary or auxiliary air supply is admitted through the openings.

In operation, the pressure in the mixing chamber is lower than that of the atmosphere; the degree of vacuum depends on the amount of throttle opening, the engine speed, and the amount of opening for the primary and secondary air supply. Gasoline, as it is sucked out of the nozzle, made up as it is of hydrocarbons of different values from the point of view of weight and volatility, will hold to the globular form with more or less tenacity, depending upon conditions.

It should be noted that doubling the diameter of these globules increases their surface four times, but their bulk will be increased eight times. Evaporation is proportional to the surface, but if doubled the quantity reside under a given surface, double the time must be taken to gasify the liquid, subject to a correction in that the spheroids are reducing in diameter as the vapor expands. Hence, the importance of constructing the nozzle so that it shall discharge gasoline in as finely divided state as possible.

Lowered pressure tends to cause vaporization, which begins as soon as the fuel has left the nozzle. It is impossible to measure or estimate the extent of the vaporization at the nozzle or through the manifold, due to this pressure reduction, but it is known to be very appreciable in its effect. It should be considered as a condition affecting vaporization at the nozzle end but slightly, but to a much greater extent after the fuel has become suspended in the air.

Those who have constructed transparent mixing chambers for the observance of nozzle action, have ascertained that the fuel left the nozzle as a solid stream or in heavy globules, not as a fine spray, as it is supposed to do. A good design of nozzle and needle valve will do much to correct this, giving an increase in power output and fuel economy. However, any nozzle form will give a wet and uneven discharge with low engine demands, even though a true spray may be delivered with increased demands. Some of the fuel torn away is in small enough particles to be considered as spray or mist, and may be taken as contributing directly to the vapor content of the mixture; the greater part, however, sooner or later strikes some part of the containing walls, and is later picked up in the form of globules. These globules are continually taken up and thrown out by the air stream in its progress to the cylinders, until some of them are sufficiently small to become completely vaporized.

Whatever form be given to the nozzle, the effectiveness with which it can break up the fuel varies as the difference between the pressures at its two ends, and as the pressure difference varies through the speed range of the engine, the fineness will vary also. Since the nozzle has a very small opening, even for the largest automobile motors, it is easily stopped up, and the construction should be such that it may be easily removed for cleaning.

A vapor is the gaseous form of a substance that is ordinarily solid or liquid. The degree of vaporization in the carburetor is the fineness with which the liquid is broken up at the nozzle; the reduction of pressure within the mixing chamber, and the temperature and grade of the fuel. During vaporization by pressure reduction, that part of the liquid which vaporizes does so through the abstraction of heat from the remainder, which becomes constantly colder. Vaporization due to pressure reduction by engine suction will continue until the temperature of the liquid becomes so low that vaporization ceases, until heat is supplied from outside source. Vaporization by pressure reduction, however, can become only partially complete, since the part of the liquid which vaporizes does so through the abstraction of heat from the remainder, which becomes constantly colder.

When a carburetor is rather small for the engine which it has to supply, it becomes very cold while in operation, as the amount of heat necessary to effect the vaporization of the gasoline is more than is available from the entering air or than could be secured through the metal of the carburetor by conduction. The temperature of the metal becomes so low that water condenses on it, and in extreme cases is deposited in the form of frost. This indicates a temperature in the carburetor too low for the successful use of inferior fuel, and so low as to possibly affect the intimacy of the resulting mixture, even if high-test gasoline be used. Moreover, if any water be present in the float chamber, it will probably freeze and disturb the flow of

the gasoline. In order to overcome this, heat is supplied by providing means for heating the air supply, the mixture, or the gasoline.

The air may be heated by arranging the outside end of the air-inlet pipe so as to terminate closely to the exhaust manifold or some hot portion of the engine. The mixture may be heated by a jacket around the mixing chamber, and heat applied either by means of hot water taken from the cooling system with a shunt, or by passing the exhaust gases through the jacket. Similarly, the liquid may be heated by hot water or exhaust gases by jacketing the float chamber.

Heating the carburetor by the circulating water gives good results, but the starting of the motor is more difficult, especially in winter. Heating by exhaust gases is open to some objection, as oil and carbon soot are liable to be deposited in the heating jacket.

The fuel charge for a gas engine is composed of a mixture of about 10 to 16 parts air to 1 of gasoline vapor. The proportion varies according to the conditions of the atmosphere, quality of gasoline, and engine speed. At first it was thought that the best results were obtained with a constant mixture under all conditions. However, from experience and numerous experiments, it has been conceded that a constant mixture is not advisable, either from the standpoint of fuel economy or best operation. A constant mixture is one in which the proportion of gas and air does not vary.

To get the maximum power out of a given-sized engine the fuel should be introduced into the cylinder as cold as possible, consistent with complete evaporation, intimacy of mixture, and completeness of combustion.

A thin or lean mixture is one having a very small proportion of fuel gas. A rich mixture is one having a greater percentage of fuel gas. A lean mixture is usually the most economical.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE VI.

CLUTCHES.

(Instruction Charts Nos. 1, 2, 4, 20, 21, 39. Equipment: White, Dodge, F. W. D. clutches.)

A clutch is a movable friction coupling for connecting the crank shaft to the transmission shaft. It is so arranged that the latter may remain stationary with the former in motion until "thrown in," whereupon the transmission shaft will turn with the crank shaft. The leading requirements are: (1) Gradual engagement, (2) quick disengagement, (3) large friction surface, (4) accessibility, and (5) simple construction. It may be said that the action should be such that it does not apply the full power of the engine at once, but gradually, in order that the automobile may start slowly and without jerking. If the power be applied suddenly, the machinery may be badly strained, or again, the resistance of the stationary car may be sufficient to overcome the momentum of the engine and cause it to stop between the power strokes. A clutch is not necessary on automobiles propelled by steam or electricity, as these powers are more flexible, that is, the application of power is not intermittent, as with the gas engine. A clutch should disengage promptly in order to avoid any drag of the parts after disengagement. Large friction surfaces are necessary in order that the clutch may be capable of transmitting the maximum power of the engine to which it is applied without slip or loss. This is to avoid waste of power, and also render the clutch easy to operate.

A clutch should be easy of removal for inspection or repairs, and should be provided with suitable adjustments so that a certain amount of wear between the surfaces may be taken up without renewal of surfacing. It should be as simple as possible, of substantial design and construction, and with as few operating parts, which would be liable to get out of order, as is consistent to preserve proper operation. In the event the parts needing replacement, or of wear being serious enough to require new frictional surfaces, it should be of such construction that the replacement could be made with minimum expense.

A cone clutch consists of two members: A dish-shaped ring, secured to the face of the flywheel, and a truncated cone carried by a sleeve sliding on the main shaft, and held in close fit by means of a spring. The first member is called the "female cone" and the second the "male cone." There are two varieties of cone clutch:

(1) The external cone clutch, in which the male cone is forced against the flywheel from the rear, and (2) the internal cone clutch, in which the male cone is contained within the other member, and is forced into contact from the front. In both forms, the contact is between a metal surface and one of leather or fiber. Since it is essential that no oil or grit be allowed to collect on the friction surfaces, the internal cone clutch is preferable, as enabling the surface to be more readily protected. Sufficient friction surface, and the proper angle of the cone surface are essential in order to obtain good power transmission. Troubles are sometimes encountered with cone clutches. Unless skillfully handled, the power will be thrown on with a jerk—not gradually as it should be. The friction surfaces, when worn, are liable to slip. A multiple disk clutch consists of numerous metal disks secured alternately to the clutch shaft and to the face of the engine flywheel. The disks are compressed in frictional contact by a strong spring, thus giving a firm driving contact for transmitting the power from the engine to the transmission.

A clutch is said to be "sweet" when it properly performs its functions, that is, when it may be thrown into engagement gradually, thus applying the power by degrees, so that the car may start slowly and without jerking. A clutch is said to be "fierce" when the reverse conditions obtain, that is, when it takes up its work too quickly, causing the car to jump forward with a bound upon starting. Derangement is often caused by the clutch spring being too strong; this results in an unusual amount of power being applied to the clutch pedal in actuating the clutch, and it is apt to stick, preventing a quick withdrawal at a critical moment. The tension of the clutch spring should be made less, the friction surfaces cleaned, and a small quantity of castor or neat's-foot oil applied to them if they are of leather.

There are sometimes troubles experienced with multiple disk clutches. These are subject to three varieties of derangement: (1) Gripping, (2) spinning, and (3) slipping. Gripping is a quick, sharp engagement of the clutch. It may be caused by looseness in the foot pedal or joints, or a "give" in the lever or fulcrum. A gradual clutch engagement can not be secured when the leverage is not absolutely positive. Another cause is a too powerful spring tension. In a leather to metal contact, gripping may be caused by exhausting the oil in the leather, thereby roughening its surface. Spinning is the continued revolution of the driven member, usually caused by faulty design, poor adjustment or failure to make a complete disengagement of the two members. Slipping is usually due to a spring tension that is too weak. Another cause is the undue wear of the friction surfaces, allowing the clutch pedal to move backward till it rests against the rear end of the slot in the floor.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE VII.

TRANSMISSION.

(Instruction Charts Nos. 1, 2, 21, 39. Equipment: Dodge, White, F. W. D.)

The term "transmission," strictly speaking, includes the entire mechanism between the engine and the rear wheels, through the several parts of which power is transmitted. The gear set is simply a part of the transmission, the drive another part, etc. However, by incorrect usage, the term has come to mean only the gear set. A transmission is necessary on account of the nature of the gas engine cycle. The crank shaft of a gas engine is operated by an intermittent force, and not, as in the case of a steam engine, by a continuous pressure; hence, it will only develop its full power when running at the maximum speed. The duties of a transmission are: The first object is to allow the engine to speed up until the energy which it stores in the fly wheel is sufficient to keep the shaft revolving at a speed showing no great percentage of variation. A second and principal duty is to adapt the engine to a heavy load, which, under other circumstances, would cause it to slow down and stall, if required to work under such conditions any length of time.

It may be assumed (1) that a man is raising a bucket in a well by winding a rope around the drum of a windlass, and (2), that the bucket must be raised a certain number of feet every minute; then if the bucket of water weigh such an amount as to require all his strength to fulfill these conditions, and any extra weight added to the bucket would overtax his strength to such an extent as to make further progress impossible, it is evident that some mechanical contrivance is necessary which will enable him to exert the same strength, but apply it through a longer period of time, or through a greater distance. To make this plain, it may be assumed that he wished to lift a barrel weighing 600 pounds 10 feet. It is evident that this could not be done in a direct manner. If, however, he should build an incline long enough, he would be able to roll it up, accomplishing the same work, but taking a longer time. Another way of doing it would be by the use of a lever. Now returning to the first illustration, instead of turning the drum of the windlass direct by hand, a gear may be placed on the end of the drum and constructed to mesh with a smaller gear attached to the lever. To illustrate the principles involved, it may be assumed that the large gear on the drum is three times the diameter of the small gear. It will, therefore, require three revolutions of the small gear to one of the large gear, and the pres-

sure exerted will be only one-third of that required if the crank were fastened to the drum direct. In either case, the work done is the same. To compare this with the conditions of automobile operation, the work required to lift the bucket may be represented by the work required to drive the machine, and the man's effort, or force applied to the lever of the windlass, by the pressure exerted on the piston of the engine.

Work is the product of two factors: Force and distance through which the force acts. For a given amount of work, force and distance are inversely proportional, that is, if the distance be increased, the force will be diminished a corresponding amount. The office of the transmission is to keep the first factor—"force"—within allowable limits, by permitting the second factor—"distance"—to vary in proper proportion. The factor "distance" is represented by the distance traveled by the piston during the power strokes, and "force" by the pressure exerted on the piston during these strokes.

The majority of change-speed gears sets which have been generally fitted to automobile service are forms of sliding gear arrangements and may be divided into two main classes. In progressive sliding gear sets, but one member is employed for all speeds, and this is shifted along from one extreme position to the other. In the selective system it is possible to go into any one of the speeds, or gear ratios desired, without passing into other speeds, and with but a limited movement of the shifting members.

The sliding gear system was one of the first to receive general application in early forms of motor vehicles and in its primitive condition it was but a modification of the back gearing used on certain classes of machine tools, such as lathes, drill presses, etc. One of the advantages of this type, when compared to other gear transmissions, is that it is possible to provide a greater number of speed changes and that there is a higher driving efficiency when on the lower ratios because but two pairs of gears are in mesh.

With the selective gear set, the number of shifting members provided makes it possible to go into any speed directly without passing through the others. For instance, if it is desired to engage the high speed, this member may be pushed directly into position, so that the main shaft, and the constant drive gear are locked together. If it is desired to go into reverse, a simple movement of the operating, or shifting member, which is guided by an **H** slot gated segment, will disengage the high speed and throw the other shift member into position.

One of the advantages of this method is that it is easy to engage the gears and that the liability of injuring the gear teeth by injudicious shifting is not as great as in the progressive type. Another advantage of the selective system is that it permits a more compact construction and makes possible the use of shorter shafts which are stiffer than longer ones because the distance between points of support is not so great. Not only is the operation much easier, but it is possible to obtain the varying speed ratios much more quickly than with the progressive system.

The usual number of gear ratios provided is three forward speeds and one reverse motion. On some of the heavier touring cars four forward speeds are provided, as in the White gear box, and when this

is done, engineers differ as to whether the direct drive should be on the third or fourth ratio. When the direct drive is on the third ratio, the fourth speed is obtained by gearing-up and the driving shaft revolves faster than the main shaft of the engine. When the fourth speed is a direct drive, the crank shaft and the driving shaft turn at the same speed. The geared-up fourth speed can be used only when conditions are exceptionally favorable to high speed. If the highest speed was obtained by a direct drive the natural tendency of the motorist would be to use this most, but there would be many conditions where the ratio would be too high and one of the lower gears would have to be used. If the direct drive was obtained in the third ratio this would be employed the greater part of the time, and as there would be less wear on the gearing with the direct drive engaged, it would be preferable to use this as much as possible.

The question of which gear ratio to use depends entirely upon local conditions, and before determining the ratios of the gearing in the speed-changing mechanisms, it is imperative that a definite relation be established between the speed of the driving shaft and the road wheels. When heavy pleasure cars use engines of moderate power, the gear reduction is usually three and one-half, or four, to one, this meaning that when the gearing is in the direct drive the engine crank shaft will turn three and a half, or four times to one revolution of the driving wheels. On cars where the margin of power is large and where high speeds are desired, the ratio may be but two and one-half to one. If the car is geared too low, the engine must make a very high number of revolutions when on the highest speeds and use much more fuel than necessary. On the other hand, if the driving ratio is too high it will be necessary to change gears frequently, because even moderate grades will make it imperative to use a lower ratio than that afforded by the direct drive. There is considerable friction in the ordinary gear box, even when the high speed is engaged, because of the constant rotation of the countershaft in its bearings.

The body fitted to the car has a material bearing upon the gear ratios provided. The driving speed that would be entirely practical on a chassis fitted with a roadster body, would be much too high if a limousine, or coupe, body was fitted to the same chassis. If the car is to be operated in regions where the conditions are not favorable, such as hilly sections, or where the highways are poorly developed, a much lower final drive ratio must be provided than where the roads are good and conditions favorable to high speeds. The speed ratios when the low gears are engaged will vary from ten to one to such extremes as twenty-five to one. The intermediate speed usually varies from five to one, to ten to one, and a third ratio in a four-speed gear set may vary from three to one to six to one, and in some gear sets it may have a value of seven, or eight, to one. If the fourth speed is obtained by gearing-up one may get a ratio of drive as high as two to one, though when the direct drive is on the fourth speed it is seldom higher than three to one. Most of the sliding gear sets have at least one of the speeds a direct drive, but some forms have been devised where the power is transmitted through gears at all ratios.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE VIII.

THE DRIVE.

(Instruction Charts Nos. 1, 2, 26, 27, 39. Equipment: Dodge, White, Cadillac drive shafts.)

In the transmission of power to the driving wheels of an automobile several methods are followed. These vary according to the size and weight of the vehicle and the character of the engine, also according to the individual preference of the designer. One system is preferred to another on account of real or supposed reliability, its efficiency in economizing power, etc. The types of drive in general use are the shaft, the chain, and the spur drive. In the shaft drive method, power is transmitted from the gear box to the rear axle by a propeller shaft. The engine is generally placed at right angles to the axle; it is therefore necessary to change the direction in which the power acts. This involves the use of bevel gears at the rear axle.

A universal joint is a coupling for joining two shafts or parts of a machine endwise, so that one may give rotary motion to the other when forming an angle with it or may move freely in all directions with respect to the other. Universal joints are necessary to allow the shaft to turn freely, even though it may not be in line with the shaft projecting from the gear box. It must be remembered that the engine and gear box are mounted on the frame and that there are springs interposed between the frame and the axles, hence when the latter vibrate up and down the rear end of the propeller shaft moves also.

There are two types of shaft drive—one in which the propeller shaft is placed at an angle with the other shaft sections, and one in which the several parts are in line. The straight line drive is the name given to the latter and has advantages on account of reducing friction and wear due to the angularity at the universal joints. It is constructed so that when the car is loaded the propeller shaft is in direct line with the crank shaft. Under these conditions the drive is accomplished in a straight line, which assures the delivery of maximum power of the engine to the rear axle. On account of the action of the supporting springs a universal joint is necessary, as the shaft sections are not in line when the car is light or in motion.

A torsion rod is a rod attached rigidly to the housing or casing of the rear axle and fastened to a crosspiece on the frame near the transmission. Its object is to prevent the turning of the housing due to the thrust of the driving bevel.

A radius rod is a device designed to prevent any forward or aft movement of the rear axle, which, on account of the flexible action of the springs, may be caused by an obstruction in the road. Thus, if one wheel should strike heavy sand while its mate is on good surface the rear axle will be thrown out of line with the drive and bring undue strains on the latter. To prevent this radius rods are attached to the axle near the ends and pivoted at some convenient place on the frame. The axle, while free to rise and fall, is held at right angles to the drive.

There are two types of chain drive in general use, the single and the double. In the first method there is a chain and sprocket connection from the main shaft direct to the differential on the rear axle. A double chain drive has a separate chain for each rear wheel, driven from a transverse jack shaft, which, in turn, is driven direct from the engine and carries the differential. The double chain drive construction is found on practically all heavy cars using chain drive. Briefly, the system includes (1) a transverse center divided jack shaft driven direct from the engine or through the transmission gear by bevels to the differential, (2) a sprocket at each end of the jack shaft for providing chain connection to the hub of each rear wheel, and (3) driven wheels turning loose at the ends of a dead axle, each being driven by a separate chain on a sprocket secured to its hub.

The disadvantage of the chain drive is principally the chain, which is an objectionable mode of power transmission, especially under conditions of automobile operation. There is an additional complication of jack shaft, sprockets, etc., involving extra friction and wear. The chain drive is objectionable, as its use is accompanied by noise, excessive wear, imperfect engagement with the sprocket teeth, and poor efficiency due to inherent defects and conditions of service. M. O'Gorman, a prominent engineer, before the British Society of Arts, has credited the shaft drive with 69 per cent efficiency, and the chain drive with two chains and a jack shaft with but 50 to 58 per cent efficiency. The gradual displacement of chain drive by the shaft drive is evidence of the superiority of the latter. The chain should operate in oil, in a dust-tight case. The advantage of the chain drive is that a greater portion of the weight of the drive mechanism is supported by the frame instead of the rear axle housing; it is thus cushioned from shocks due to uneven road.

A roller chain is composed of a series of rollers, known as center blocks, joined by side links. Each roller rotates loose on a hollow core which is turned to smaller diameter at either end, to fit a perforated side piece joining the rollers into pairs. The side links are set over these side pieces and bolted in place through the cores, and in operation the rivets of a chain act as a number of auxiliary shafts and operate under friction in the same manner, but with less favorable conditions than the shaft that drives them. A chain can never be in true pitch with its sprocket. A pair of spur gears tend to a certain extent to wear into a good running fit with each other, but a chain, if made to fit its sprocket when new, does not continue to do so a moment after being made, as wear at once throws it out. This being so, it must be put up with, and involves the consequence that a chain can only drive with one tooth at a time, supplemented by any

frictional "bite" the other links may have on the base of the tooth interspaces. If the chain be made to fit these accurately, taking a roller chain for illustration, it is obvious that the least stretch will cause the rollers to begin to ride on the teeth. If, however, the teeth be made narrow, compared with the spaces between the rollers, a considerable stretch may occur without this taking place. The roller interspaces, then, should be long, to permit the teeth to have some play in them, while retaining sufficient strength.

In order that the driving sprocket may receive each incoming link of the chain without its having to slide up to the tooth face it should be of a somewhat longer pitch than its chain, the result being that the bottom tooth takes the drive, this being permitted by the tooth play. This difference, of course, gradually disappears as the chain stretches. The back wheel sprocket, on the other hand, should take the drive with its topmost tooth, and hence should be of slightly less pitch than the chain, but as the pitch of the latter constantly increases, it may be originally of the same pitch. The only remaining point with regard to design, and one which the owner of the car may easily insure, is that the number of teeth in the sprockets be prime to that of the links in the chain. The cause of the snap and rattle of a chain is that even with the best designed sprocket, as each tooth in turn passes out of engagement with the chain, the next roller must be drawn forward through an appreciable distance before engaging a tooth. This action not only produces the noise but is an important factor in waste of driving power.

In order that chains have the proper attention the principal points to be observed in the use and care of sprocket chains are: (1) To maintain the proper tension in order to avoid "whipping"—which, particularly with a long one, is liable to result in snapping of the chain—and, at best, involves a loss of driving efficiency. The chain should not be drawn too tight. Some slack must always be allowed.

(2) The sprockets should always be kept in alignment. In the case of a double chain drive, from a counter shaft parallel to the rear axle, care should be exercised to maintain the parallelism, even preferring a somewhat loose chain to a tight one that strains the countershaft.

(3) If a link shows signs of elongation, it should be replaced by a new one. (4) Whenever the chain is removed for cleaning or other purpose, it must be carefully replaced, so as to run in the same direction as formerly, and with the same side up. The chain should never be turned around, or its direction between the sprockets reversed.

(5) A new chain should not be put on a much-worn sprocket. (6) A chain should be frequently cleaned and rubbed with graphite, because the chief difficulty involved in the use of driving chains is the liability to clog and grind with sand, dust, etc. (7) After steady use for a more or less extended period, the chain should be removed and cleaned throughout.

A chain may be best cleaned, after removing it from the sprockets, by cleaning first in boiling water, then in gasoline, in order to remove all grease and dirt. A common practice is to boil the chain for about half an hour in mutton tallow, which forms an excellent inside lubricant. After boiling, the chain is hung up until thoroughly cool, at which time the tallow is hardened. It may then be wiped off clean, and treated with a preparation of graphite, or a graphite alcohol solution on its inner surface. Some authorities recommend that the

chain, after it is cleaned in boiling water and gasoline, should be soaked, first, in melted paraffin for an hour at least, and then in a mixture of melted mutton tallow and graphite. After each soaking it is dried and wiped clean. With either process, a daily application of graphite is desirable.

It is not necessary that both chains be of equal tightness, as the differential gear on the jackshaft will counteract this and cause each chain to do its share of the driving. The jackshaft and rear axle should be made parallel by adjusting the radius rods to secure the proper engagement of the chain with the sprockets.

Transmission of power by spur gears, as from engine shaft to differential drum, or to an external or internal gear on each of the rear wheels, is, in some respects, desirable. The drive between spurs is steadier, and is attended by smaller loss of power than between chains and sprockets, or bevels.

A number of designers have used worm gearing in connection with shaft-driving systems instead of the bevel gears so generally adopted. The advantages of the worm gear are more apparent in motor-truck construction than in pleasure car practice, though it has been used to advantage in both classes of vehicles. A high degree of efficiency has been obtained by using worms of peculiar tooth formation which have a spiral angle often approaching 45 degrees. Such worm may have from 6 to 10 or 12 threads, and they are perfectly reversible, when contrasted to the single threaded worm used in steering gears, which are an irreversible form. Obviously the worm employed for driving an automobile must be perfectly reversible to be practical, as very often conditions will be such that the rear wheels and worm gear to which they are attached must turn the worm and driving shaft, as in descending hills, with the rear axle overrunning the engine.

This form of gearing offers many inducements and has positive advantages which commend it as a means of direct final drive. Any range of reduction that would be likely to be needed may be obtained with but a single pair of worm gears, and reductions of 20 to 1 may be as easily accomplished as securing the higher ratios without the efficiency of the combination being affected. It would not be possible to obtain as low speed reduction as possible with worm gearing by the use of a single set of bevel gears or a single pair of sprockets and chain connections, because the driven member would have to be of such large size that it would be difficult to place it within the confines of an ordinary axle.

Among some of the advantages advanced in favor of worm gearing may be cited: It is silent in operation; when properly designed it will transmit 85 to 90 per cent of the engine power to the rear wheels on direct drive, and it is extremely enduring. Its efficiency under ideal conditions is equal to the most accurately machined and finely adjusted bevel gearing, and instead of the efficiency becoming less as the gearing wears, it actually becomes more silent and freer running with use.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE IX.

THE DIFFERENTIAL.

(Instruction Charts Nos. 2, 12, 26, 27. Equipment: Dodge, White.)

When a car travels around a curved path, the distance traveled by the outside wheels is greater than that traveled by the inside wheels. As the front wheels are loose on the axle, they can turn at different rates to compensate for this difference. Since both rear wheels are driven by the engine, it is necessary to apply a device that will permit them to rotate at different speeds, and receive an equal division of the power. To accomplish this, a system of gears, called the differential, is provided. The differential may be defined as a system of gears, which permits one wheel to travel independently of the other while going around a curve, so that the outer wheel may accommodate itself to the longer path it has to travel.

There are three types of differential in general use: the bevel, the spur differential, and worm. The bevel type is the original form and is largely used. The sprocket or drive wheel has secured to its inner rim several studs carrying bevel pinions, which, in turn, engage a bevel gear wheel on either side of the sprocket. These gear wheels, last mentioned, are rigidly attached on either side to the inner ends of the center divided axle bar, one serving to turn the left wheel, the other the right. When power is applied to the sprocket, causing the vehicle to move straight forward, it may be readily understood that the bevel pinions, secured to the sprocket instead of rotating, which would mean to turn the drive wheels in opposite directions, remain motionless, acting simply as a kind of lock or clutch to secure uniform and continuous rotation of both wheels. So soon as a movement to turn the vehicle is made, at which time the wheels tend to move with different speeds, the resistance of the wheel nearer the center, on which the turn is made, tending to make it turn more slowly than the other, as may be observed, these pinions begin rotating on their own axes. Thus, while allowing the pivot wheel to slow up or remain stationary, as conditions may require, they continue to urge forward the other at the usual speed.

The principles upon which the operation of the differential depends may be expressed under four heads: (1) When the resistance offered by the two drive wheels and attached gear is the same, as when the car is driven forward, the pinions can not rotate, (2) when the resistance is greater on one wheel than on the other, they will rotate correspondingly, although still moving forward with the wheel offering the lesser resistance, (3) the pinions may rotate inde-

pendently on one gear wheel, while still acting as a clutch on the other giving sufficient power to carry it forward, and (4) if a resistance be met of sufficient power to stop the rotation of both wheels and their axles, the condition would affect the entire mechanism, and the pinions would still remain stationary on their own axes.

For light service the sprocket or spur drive generally carries two pinions, as shown in the chart, but in larger vehicles the number is increased to three, four, or six and the size, pitch, and number of teeth are varied, according to requirements. Of course, it is essential that the equalizing gears be properly chosen for the work they are to perform, in the matter of the number of pinions and their teeth, as well as of the metal used, on account of the great strain brought to bear on them.

In the spur differential, the theory of compensation is the same as with bevel gearing; a divided axle, or jack shaft, whose two inner ends carry gear wheels cut to mesh with pinions attached to the sprocket pulley. These pinions are, however, set in geared pairs, with their axes at right angles to the plane of the sprocket. The pinions of each pair are set alternately on one side or the other of the sprocket, meshing with one another in about half of their length, the remainder of each being left free to mesh with the axle spurs on the one or other side. With some differentials, the divided axle carries internal gears, with others, true spur wheels. The operation is obvious. When the vehicle is turning, one rear wheel moves less rapidly, causing the pinion on which it is geared to revolve on its mate, which, in turn, revolves on its own axis, although still engaging the gear of the opposite and moving wheel of the vehicle.

The action of the differential pinions may be clearly understood by reference to the chart and giving due consideration to the following principles: The same resistance at the point of contact between the driving wheels and the ground prevents the pinions from revolving on their own studs, and in this case they are carried around by the supporting members and the ring gear. If the resistance upon the right axle shaft is greater than that on the left axle shaft, the ring gear will rotate forward with the wheel offering the least resistance and the differential pinions will turn on their studs and run over the surface of the gear which tends to remain stationary, this being the one against which there is the greatest resistance. The differential pinions can thus turn independently of one gear wheel and run over its surface without turning it, and at the same time act as a clutching member of sufficient capacity on the other gear and axle to carry them in the same direction as the ring gear and at a ratio of speed which will depend upon the difference in resistance between the driving members and the ground.

While the differential gear described is of the bevel pinion type, other forms have been devised in which the differential action is obtained by means of spur gearing which utilizes the same principle of compensation. The differential gear which utilizes bevel pinions is the form that is more generally used. The differential gear is usually incorporated in the rear axle if the drive is by shaft, and in the countershaft if transmission is by means of side chains. The construction of typical differential gears and bevel-driving gear assembly is shown in the chart: the former is utilized on light vehicles

and is mounted on flexible roller bearings, while the other construction is a type more suitable for heavier cars and is mounted on tapered roller bearings.

A worm gearing in connection with shaft driving systems instead of the bevel gears is used, and is very efficient. The advantages of the worm gear are more apparent in motor-truck construction than in pleasure-car practice, though it has been used to advantage in both classes of vehicles. A high degree of efficiency has been obtained by using worms of peculiar tooth formation which have a spiral angle often approaching 45 degrees. Such worms may have from 6 to 10 or 12 threads, and they are perfectly reversible, when contrasted to the single-threaded worm used in steering gears, which are an irreversible form. Obviously the worm employed for driving an automobile must be perfectly reversible to be practical, as very often conditions will be such that the rear wheels and worm gear to which they are attached must turn the worm and driving shaft, as in descending hills, with the rear axle overrunning the engine.

This form of gearing offers many inducements and has positive advantages which commend it as a means of direct final drive. Any range of reduction that would be likely to be needed may be obtained with but a single pair of worm gears, and reductions of 20 to 1 may be as easily accomplished as securing the higher ratios without the efficiency of the combination being affected. It would not be possible to obtain as low speed reduction as possible with worm gearing by the use of a single set of bevel gears or a single pair of sprockets and chain connections, because the driven member would have to be of such large size that it would be difficult to place it within the confines of an ordinary axle. It is for this reason that most motor-truck manufacturers use a combined bevel gear and chain drive and a double reduction of speed between the engine and the rear wheel.

Among some of the advantages advanced in favor of worm gearing may be cited: It is silent in operation; when properly designed it will transmit 85 to 90 per cent of the engine power to the rear wheels on direct drive, and it is extremely enduring. Its efficiency under ideal conditions is equal to the most accurately machined and finely adjusted bevel gearing, and instead of the efficiency becoming less as the gearing wears, it actually becomes more silent and freer running with use.

Many of the more progressive manufacturers of motor trucks are using the worm and worm-gear drive. It has been used with success in pleasure-car applications, but its greatest field of usefulness will undoubtedly be the commercial vehicle industry because of its undoubted superiority over all other forms of gearing from which considerable reductions in ratio are demanded and where the efficiency of the transmission system should be conserved as much as possible. A typical worm-gear assembly and the method of mounting the worm in connection with the shaft drive is shown in the chart.

The arrangement of a worm-gear driving axle is outlined in the chart, with all parts shown. It will prove useful in showing the actual relation of the various parts to each other. The worm is

mounted above the worm gear and is supported by two single-row ball bearings of the annular type which take the radial stresses. As there is also a large end thrust, due to the angle of the worm teeth, it is necessary to use a double ball-thrust member at the rear end of the worm to take the end thrust which is present whether the worm gear is being revolved to drive the vehicle forward or backward. As will be seen by the longitudinal sectional view through the rear construction, the worm-drive assembly is used in connection with a live axle, and the worm gear is attached directly to the case which houses the differential gears. The differential assembly is supported on large single-row annular ball bearings, while end-thrust bearings of the ball type are provided to hold the differential assembly in place positively so that the worm and worm wheel can not be forced out of correct engagement by the end thrust existing on the worm gear. The drive from the differential to the wheels is by conventional live-axle shafts.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE X.

RUNNING GEAR.

(Instruction Charts Nos. 1, 2, 22, 23, 24, 25, 26, 27, 29, 39, 40, 41, 42. Equipment: Dodge, White trucks.)

The term running gear includes such parts as the frame, springs, axles, wheels, brakes, and steering gear. In early construction, automobiles were built with some form of underframe, whose essential elements were "perches" connecting the front and rear axles, as in most horse carriages, and some form of swivel joint to permit of considerable distortion, in compensation for unevenness on the roadway. The two objects sought in this supposedly necessary structure were strength and flexibility. Many designers used complicated forms of steel tubing, with the additional object of securing lightness. These elements have since been almost entirely abandoned, except in a few light steamers and electric wagons, for designers learned by experience that with properly arranged springs an automobile can be strong and flexible, without perches and swivels, and light without steel tubing.

The modern frame consists of a rectangular frame, built of steel channels, suitably braced, and having several cross members. Attached to the ends are springs designed to absorb the vibration and shocks. The springs generally used are known as the "leaf spring," and consist of several layers of steel plates or leaves slightly bent, so that, when laid together, they form a series of superimposed arcs. It is important that the line of the arc formed by the spring be carefully followed from end to end of each plate, and that no attempt be made to straighten or bend back the extremities of the longest leaves. This is true, because the spring effect is derived from the temper of the metal in permitting the load to flatten all the arcs at once under a single stress, which involves that they should slide upon one another in altering their shape, as could not be the case were there any departure from the line of the arc.

The elliptical, the semielliptical, and the three-quarter elliptical are three forms of springs used. The elliptical spring is formed by connecting two semielliptical or arc-shaped springs at their extremities—generally by bolts passed through perforated bosses formed at the ends of the longest leaves—and is attached to the apex of each arc by clips, or nuts. The semielliptical spring consists of a segment formed by a number of leaves or blades and is arranged to be attached

at the bottom and two extremities of the arc. The three-quarters elliptical spring differs from the semielliptic in having one extremity of the arc rolled up and turned inward. It may be attached by a link or a shackle to a flat or semielliptic spring—forming a “scroll elliptic”—or to the body suspended above the axle. Resistance and resilience are essential in a good spring. While a spring should be calculated to give sufficiently to absorb the jars of travel, it should not be so resilient as to rebound with a series of vibrations. A shock absorber is a device for insuring the gradual return of a spring to its original shape after being compressed, so as to deaden its rebounds and after movements by absorbing them with some form of frictional resistance.

A torsion rod is a rod rigidly attached to the housing of the rear axle, and flexibly fastened to a cross member of the frame near the transmission. A second form of torsion rod is a modified construction consisting of a cylindrical sleeve, enclosing the propeller shaft, and attached rigidly to the bevel gear case; it is pivoted at the other end of the frame, or carried by a bearing on the shaft. A torsion rod resists the torque or twist due to the thrust of the propeller shaft pinion, which tends to cause the housing to revolve.

A radius rod is a rod used with a chain drive to resist the pull of the chain and maintain the rear axle at a fixed distance from the jack-shaft. A torsion rod resists the twist on the gear member, due to the action of a shaft drive, while a radius rod resists the thrust on the rear shaft caused by chain drive. With chain drive, the radius rod describes an arc, as the axle rises and falls in travel. With shaft drive, a slip joint on the shaft is sufficient to compensate for the varying angle of the shaft.

The distinction between a “dead” and a “live” axle is that a dead axle does not turn; a live axle turns with the wheels. A semi-floating axle is one in which the wheels are secured directly to the transverse rear axle; it not only serves to turn the wheels, but also to support the weight of the car. A floating axle is one in which the wheels have a bearing entirely upon the rear axle housing, so that the weight of the car is carried entirely by the housing. The axle in this construction serves only to transmit the motive power to the wheels.

Automobile wheels should have the following qualities of construction: (1) They must be sufficiently strong for the load they are to carry, and for the kind of roads on which they are to run. (2) They must be elastic, or so constructed that the several parts—hub, spokes, and felloes, or rims—are susceptible of a certain flexibility in their fixed relations, thus neutralizing much vibration, and allowing the vehicle greater freedom of movement, particularly on short curves and when encountering obstacles. (3) They must, furthermore, be sufficiently light to avoid absorbing unnecessary power in moving. (4) They must be able to resist the torsion of the motor, which always tends to produce a tangential strain. This is the reason why tangent suspended wire wheels are used on automobiles, instead of the other variety, having radial spokes. (5) They must have sufficient adhesion to drive ahead without unduly absorbing power in overcoming the tendency to slip on an imperfect road. The importance of the last two considerations may be readily understood, in view of the fact that the wheels receive the driving power direct, instead of being merely rotating supports, like the wheels of horse-drawn vehicles.

The approved type of wheel is the wooden, or so-called "artillery wheel."

The slight inclination of the spokes from the outside plane of the rim inwardly, so as to make the wheel a kind of flattened cone, is called "dishing." The advantage of this construction is that it transforms the spokes into so many springs, possessing elastic properties, and renders the wheel capable of being deformed under sidewise stress. The shocks of collision with obstacles are thus distributed through the flexibly connected parts, as could not be the case if the wheel were made in one piece, or on one plane, and the consequent wear and strain is greatly reduced.

The larger the wheel, the smaller the shocks experienced in passing over inequalities in the road. Thus it is that a wheel 5 feet in diameter will sink only one-half inch in a rut 1 foot wide, while a 30-inch wheel will sink nearly three times as deep, with the result that the resiliency of its tires must be much larger, in order to compensate for the greater shock experienced. The larger wheel also rises less quickly over obstructions. There are, however, other methods for neutralizing the shocks on rough roads. The end of obtaining a low and easy running rig may be achieved quite as well by increasing the length of the vehicle, the length of the springs, and the size of the tires, as by adding to the height above the ground. Also, the broad tire is superior to the narrow one in the very same particular—that it will not sink so quickly into mud and sand, and, by its greater buffing properties, neutralizes the concussion otherwise experienced with small wheels. These and other considerations have largely determined the prevalent practice of using wheels of moderate diameter for automobiles.

Tires.—Tires are used on automobiles, motorcycles, and a large number of horse-drawn vehicles, to secure a desirable spring effect or cushion, so as to reduce vibration to a minimum, and to obtain a large traction area to prevent the wheels sinking in soft roadway.

The most efficient shock-absorbing medium is compressed air. This method of reducing vibration, however, as exemplified by the pneumatic tire, has the disadvantage that rubber, which is the only elastic air-confining substance available, is liable to puncture.

There are in general use three varieties of tire: Solid, cushion, and pneumatic. As is generally known, the pneumatic tire was first devised in order to furnish the needed resiliency in bicycles, and for the same purpose it has been found useful in automobiles. It is also superior in point of tractive qualities, "taking hold" of the roadbed far more effectively than the best solid tire. It has, however, one notable disadvantage, the constant liability to puncture, with the consequent danger of being rendered useless. In order to remedy this defect, inventors and manufacturers have introduced such features as thickening the tread of the tire, increasing its resistance to puncture by inserting layers of tough fabric in the rubber walls, and reinforcing the tread surface in various ways. Pneumatic tires are almost universally used on automobiles, the solid type being confined to electrics and trucks intended for city service.

Cuts, due to stones or other sharp obstacles, tend to spread to the center of the tire, across the tread. This is due to the quality of the strains transmitted from the wheels, and in order to prevent the de-

struction of the tire, it is necessary to vary the shape. Accordingly, tires are made with beveled edges, rather than on square lines. This conformation, together with a good width at the rim, is able to provide for absorbing much of the surplus vibration, while decreasing the ill effects due to the combined action of a heavy load and road resistance. The most valuable quality of the pneumatic tire is its resiliency, or ability to bounce in the act of regaining its usual form after encountering an obstacle in the road. On encountering a stone, for example, it will yield to a certain extent, absorbing or "swallowing it up," at the same time exerting a pressure sufficient to restore its normal shape. The latter quality has two advantages for easy riding: (1) It does away with much of the lifting up of the wheel in passing over obstacles, which is otherwise inevitable, and (2) it enables the tire to obtain a better grip on the roadbed.

A pneumatic tire consists of an inner tube, which contains the compressed air, and an outer casing or shoe; the shoe is open along its inner circumference, has projections or flanges which fit snugly into channels formed by inturning the edges of the rim to hold the tire in place. These channels are the "clinchers," hence the name "clincher tire." Sometimes the inner tube is protected by a "flap." In removing the shoe, it is necessary to insert a flat tool between it and the rim and pry them apart. This operation is tedious, and also involves severe strain on the fabric. A careless hand may also cut or bruise the inner tube, particularly when it is not protected by a flap.

Tires should be kept in cases, such as are provided for the purpose by tire dealers. This rule applies with particular force to the very elastic inner tubes, which should be stored in bags in some convenient place away from the light and heat of the sun. Tires in use are not as liable to injury from sunlight as the extra stored tires, for the reason that the dust and mud of travel, while not directly contributing to the advantage of the rubber, seem to neutralize the ill effects of the sun's rays. This is the best explanation of the fact that used tires are less liable to injury than new ones. Some forms of wear and tear of pneumatic tires are (1) puncture, (2) rim cutting, (3) cracking of the walls, (4) excessive wear on the walls or tread, and (5) chemical action.

The causes of rim cutting are:

(1) Sand or sharp particles lodged between the tire and the edges of the rim, which, particularly when the tire is partially deflated, cut through the outer layer of rubber to the fabric beneath.

(2) Overloading. This causes the tire to flatten, in spite of persistent extra inflation, and the result is nearly always shearing off at the edges near the points where the flanges engage the clinches.

(3) Defective or bent rims. Rims may be unsuited for given makes of tires because made for some other style. It is essential that the tire fit the rim perfectly, since if the attachment be not tight, movement and chafing result, or stones and sand find lodgment; if it be too tight, the pressure against the edges of the rim is excessive. Loose or ill-fitting studs always allow some movement of the tire, which usually results in cutting, at least in spots around the rim. These mishaps occur less frequently than those due to bent or rusty rims, which work the same havoc as those that fit

poorly. It is necessary to keep the rim in repair and to clean out all the evidences of rust.

(4) Insufficient inflation. This is often a cause of cutting, even when the rims are in good condition. It is necessary to keep the tires pumped hard at all times. If cutting then results, it is evident that the tires are too small for the load they are obliged to carry.

(5) Sharp curves or excessive "side step." Both tend to produce a pressure that is concentrated at the rim, and, in proportion to the weight of the car, or the speed at which it is driven, are liable to result in cutting of the shoe. Side slipping or skidding is largely neutralized in cars with long wheel base, but, even with this desirable structural feature, occasions may arise in which rim cutting results from sudden turns.

If a tire be well made, any evidence of cracking of the shoe may safely be attributed to driving with insufficient inflation. As a result of a puncture or other mishap, all the air may be exhausted, causing the tire to be completely flattened under the weight of the vehicle. This is liable to cause cracking. Long-continued pressure of this kind tears and destroys the fabric of the tire. It is important to keep the tire inflated to the proper pressure. To neglect this will cause the rapid deterioration of the tire. Running a tire flat, even a short distance, will prove expensive.

The brake should not be applied suddenly unless absolutely necessary.

When one side of a tire shows more wear than another, it should be turned around, so as to reverse the sides.

High speed is very destructive to tires.

Grease and oils should be carefully kept away from tires; they attack the rubber.

Rims should be kept in good order, straight and true. Rust is destructive. Paint preserves.

The weight of the cars should not rest on deflated tires, not even over night.

It is better to run on the rim, very slowly and carefully, if necessary and the distance be short, than on a flat tire.

Rear tires wear the more rapidly. Front and rear tires can therefore, be transposed sometimes to advantage.

The throttle should be used more, and the brakes less, in controlling the car. This saves both the tires and the machine.

ELEMENTARY AUTOMOTIVE ENGINEERING.

LECTURE XI.

MOTORCYCLES.

(Instruction charts Nos. 7, 22, 23, 40, 41, and 42. Equipment: Indian or Harley-Davidson motor cycle.)

According to experience in the matter, a motorcycle must be propelled by an engine of somewhat higher power rating than is actually required for the load to be carried. The reasons for both conditions are apparent, since, having dispensed with the water cooling and circulating system for sake of lightness and compactness, it is desirable to avoid overheating which would occur at high engine speeds, and such low power as would cause the engine to labor under ordinary loads. Motorcycles, although much cheaper than automobiles, are capable of the same speed as the average car; moreover, the expense of fuel and upkeep is very small.

Engines of from two to seven horsepower are usually fitted to motorcycles. About four horsepower is suitable for ordinary use. The frame and wheels are both made heavier and stronger than in foot-propelled machines. The tubes are made with thicker walls, and the joints more securely reinforced. In several makes the end of security is further assured by struts and trusses, particularly at the fork on the steering post and at the place where the engine is hung.

A one-cylinder four-cycle engine is in common use, although two and four cylinder engines are used on the higher powered machines. The "V" twin-cylinder engine is generally used; it is popular on account of its simplicity and lightness, there being only one crank and cam shaft for the two cylinders. It is located in a very low position, so as to keep the center of gravity low, and make the machine easy to balance. With this location, the rider does not have to straddle a hot engine, and the air strikes directly on the cylinder head. There has been a wide diversity in design in the location and mode of attaching the engine to the frame. In some makes it has been supported on the backstays, between the pedal bearing and the rear wheel; in one make on an extension of the backstays to rear of the wheel; in several makes it is supported against or forms a part of the rear or saddle tube member of the "diamond" frame. The favorite position at the present time is on the forward part of the frame, in front of the pedal bearing or on a tube arranged beneath, and suitably trussed to hold the weight.

Motorcycles are always air cooled. The engine is lubricated by the splash system: oil is placed in the crank case and the motion of the fly wheel and connecting-rod end splashes it on the bearings, piston, and cylinder walls. The valves are generally offset on one side of the cylinder, being arranged one above the other. It is usual to fit the exhaust valve with a lifter to hold the valve off its seat and thus relieve compression in starting. This is operated by a conveniently located lever. A spiral spring effects the return of the lever to its original position.

Both inlet and exhaust valves are placed in the same pocket. The inlet valve of the twin cylinder is operated by a lift rod, worked by the cam, and a rocking lever that is mounted on the dome of the valve chamber, and an adjusting screw is provided in the end of this rocking lever to regulate the amount of the opening in the valve. The valve chamber dome is secured in position by a bayonet joint, and may be removed, after disconnecting the induction pipe, by giving it a quarter turn. The inlet valve, with its seat, spring, etc., comes out with the dome, from which they are withdrawn by the fingers. The removal of the dome exposes the exhaust valve for inspection. The high tension or jump-spark ignition is generally used. A magneto is used for ignition and works on the same principle as on a motor vehicle, except that instead of having four contact points it has only two (one for each plug).

Some spring arrangement is included in the saddle post. In addition, a spring fork for the front wheel is usually provided for absorbing the jar. The speed of the machine is usually regulated by adjusting or throttling the mixture and varying the time of the spark, also by cutting out the ignition so as to miss explosions. With some types of engine, the timing of the valves and spark is fixed so that unless wrongly assembled at the factory there is no chance of trouble excepting, of course, in the event of the rare, but possible, breakage of a gear tooth.

There are three kinds of drive used on motorcycles—the belt, the chain, and the shaft drive. The objections to the belt drive are that it requires adjustment, and must be kept in tight contact to prevent slippage of the small driving pulley on the engine: slippage results in loss of power. A belt deteriorates rapidly, due to moisture, dirt, etc., hence, it requires frequent repairs and renewal. The use of round, V-shaped and even flat belts, does not always give satisfaction. The great tension to which belts have to be subjected in order to insure proper adhesion, and still more, the alternate actions of dry and wet weather, cause them to stretch. This drawback frequently necessitates repairs on the road. Finally, the traction exercised by the belt on one of the ends of the hub hinders the proper working of the latter.

The chain, and shaft drive furnish a positive connection between the engine and rear wheel. The chain drive is furnished on a number of the medium-priced machines, and the shaft drive on the more expensive machines. While the chain is a satisfactory and inexpensive drive, the shaft with its inclosed gears is entirely protected from dust and does not present any lubricated surfaces to soil the rider's clothing.

The transmission used on some motor cycles is provided with a three-speed and free-engine transmission; others have in place of sliding

gears a form of friction clutch by which the power may be gradually applied in starting. The advantages gained by the use of a transmission are that it enables the rider (1) to climb steeper hills, (2) makes it possible to stop and restart at will without dismounting, either on level road or on the steepest hill, by means of the free engine, (3) to slow down or even come to a dead stop, if "pocketed" in a congested street, and (4) restart without pedaling.

In operating a motor cycle before starting: (1) the various parts of the machine should be carefully examined, (2) the gasoline tank and lubricating devices filled, (3) gasoline valve opened, (4) carburetor primed and throttle opened, (5) the exhaust valves raised, (6) ignition cut-out plug inserted, (7) handlebar ignition switch opened, and (8) spark well advanced by means of the lever provided for the purpose. As soon as the engine begins to operate, the spark should be retarded and adjusted together with the throttle to meet the speed requirements. On motor cycles, as a rule, the speed is varied chiefly by the spark position. The control of the machine, at slow speeds, is made more flexible by the use of the handlebar ignition switch.

In descending a hill: (1) the ignition should be cut out with the handlebar switch, (2) throttle closed, and (3) exhaust valves lifted; the latter operation relieves the drag of the engine and admits fresh air to the cylinders, which has a tendency to keep the spark plug points clean and clear the cylinder of carbon deposits. In operating a motor cycle, it is important that the lubrication of the engine receive frequent attention—say every 10 miles. The crank case should receive sufficient oil that it may splash up against the piston and cylinder walls. Occasionally the crank case should be drained, washed out with gasoline, and a fresh supply of oil provided. When it is desired to stop: (1) the ignition should be cut out by the handlebar switch, (2) exhaust valve lifted, and (3) brakes applied. Gasoline is supplied by gravity, from a tank located over the motor, to the carburetor which is located on the side of the engine midway between the cylinders.

Pneumatic tires are used on both front and rear wheels. Brakes are of the contracting band type, and are operated either by a foot pedal or by hand. The clutch is operated by either the foot or hand.

LABORATORY EXERCISE SPECIFICATIONS.

These are intended to afford a basis (1) for equipment necessary for a unit and (2) for student assignment.

	Students.	Time
Oil pumps (2).....	2	1 hour.
Carburetors (1) sectionalized; assembled.....	1	1 hour.
Oiling systems complete (1).....	2	1 hour.
Gasoline system complete (1).....	2	1 hour.
Vacuum system complete (1).....	1	1 hour.
Governors (2).....	1	1 hour.
Radiators (1).....	1	1 hour.
Water pump (1).....	1	1 hour.
Chassis complete.....	1	3 hours.
Storage batteries (1).....	1	1 hour.
Storage batteries (1) sectionalized and disassembled.....	1	1 hour.
Coils (2).....	1	1 hour.
Distributors (2).....	2	1 hour.
Ignition set complete (1).....	2	1 hour.
Generators (1 assembled; 1 disassembled; 1 sectionalized).....	2	1 hour.
Cut-outs (2).....	1	1 hour.
Magneto and plug assembly (1).....	1	1 hour.
Switch and fuse blocks (2).....	2	1 hour.
Starting motor clutch (1).....	1	1 hour.
Clutch assembly (1).....	2	1 hour.
Propeller shaft assembly (1).....	1	1 hour.
Rear axle assembly complete (1).....	2	3 hours.
Front axle and steering mechanism (1).....	2	2 hours.
Wheels and tires (5).....	5	1 hour.
Brake assemblies (2).....	2	1 hour.





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